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CAPE OF GOOD HOPE.

DEPARTMENT OF AGRICULTURE.

ANNUAL REPORT

OF THE

GEOLOGICAL COMMISSION.

1901.

Presented to both Houses of Parliament by command of His Excellency the Governor
1902.

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1901.

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Geological Commission of the Colony of the Cape of Good Hope.

1901.

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Superintendent-General of Education.

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ERNEST H. L. SCHWARZ, A.R.C.S., F.G.S.

Museum Assistant—
MISS M. WILMAN.

Cape Town,
28th July, 1902.

The Hon.
The SECRETARY FOR AGRICULTURE.

SIR,—I have the honour to forward the Report of the Geological Commission for the year 1901. During the whole of this period the unfortunate state of the country prevented the geologists from proceeding with the field-work necessary to link up the survey in the South-western area in order to complete the section of the maps of that portion of the Colony which it is desired to issue as soon as practicable. Their work was therefore carried on in the Transkeian Territories, where information of considerable scientific value has resulted. The declaration of peace will enable the work in the Colony proper to be resumed.

I have the honour to be,
Sir,
Your obedient Servant,
JOHN X. MERRIMAN,
Chairman.

GEOLOGICAL SURVEY

OF THE

COLONY OF THE CAPE OF GOOD HOPE.

DIRECTOR'S REPORT FOR 1901.

The first working months of 1901 were devoted to a re-examination of those parts of the districts of Swellendam, Heidelberg, Riversdale, and Mossel Bay, where the conglomerate and shale, which were included in former reports under the term Enon Conglomerate, had been found to play a conspicuous role. This was deemed desirable for two main reasons,—first, because we thought it would be well for the Assistant Geologists to spend to advantage a few weeks near home, till events should show how the military problem was going to be solved, and second, because the work of the former year in the Uitenhage and Port Elizabeth districts had resulted in much light being shed on the nature and relationships of the conglomerate, sandstones, and shales there forming the series, and thus given some means of more exactly defining the series here in the south-west of the Colony. Besides, there was the further prospect offered of an examination of the new cuttings made in the extension of the Cape Central Railway eastwards.

The work, though by no means exhaustive, was productive of much additional knowledge, as may be gathered by reference to Appendix I. It is obvious that, as I pointed out in the report for 1900, the Uitenhage Series is one which will require a great deal of detailed working before its peculiarities are thoroughly realised, and here again the need for a thoroughly good topographical map makes itself more than ever felt. The present map, on which all the geological field-work has to be plotted, is most unsatisfactory and the Geologist may well hope that the cry which has made itself heard from those in charge of military operations as to the worthlessness of our Colonial maps, will have some effective result. The fruits of the Geological Survey are largely thrown away if the localities where certain phenomena are observable cannot be exactly found by aid of the map, when any one is searching for them, and further, it is only when one has a clear and convincing presentation of the facts on a map that many of the geological problems continually arising can be solved. We have so often been brought up by the inadequacy of the present map that I make no excuse for again urging that attention should be given to this great need.

It will be seen in the sequel that the term "Uitenhage Series" has been used for the rocks in the south-west which, in 1898, we were content to name "Enon Conglomerate." This is a result of the acquaintance made with the series in the Eastern Province during 1900, and given in detail in the report of that year. There can be little doubt that in the south-west we have representatives of more than the restricted "Enon Conglomerate" of the east, though even yet no attempt at a definite correlation is possible.

The new light thrown on the character and distribution of the superficial deposits by the recent work of Messrs. Rogers and Schwarz is of some importance. The portion of the map published with the Report for 1897 requires much correction in this respect. The conglomerate at Worcester and Ashton should be shown as belonging to the Uitenhage Series, while to the east a good deal of the conglomerate and quartzite is much more recent. The weathering of a conglomerate like the Enon, and the re-cementing of the débris, produces newer rocks very like the older ones, and thus mistakes are easily possible both ways. Now, however, the Assistant Geologists have been able to recognise many features characteristic of the newer deposits, and thus separate them from the older rock with practically no trouble.

After some eight weeks' work in the south-west, the incompatibility of geological work with the necessities of Martial Law became so conspicuous, that we all felt that, if the survey was to be carried on, it must be in a region free from military rule. The only Colonial territory where such was the case, was the Transkei, and consequently that region became the scene of the labours of the Assistant Geologists. This has of course helped again to postpone the production of a completed piece of the map as planned. Under normal conditions we might have hoped to be able now to publish the geology of the whole area represented in the south-western quarter of the Surveyor-General's map of 1895. As matters really stand, we have a great blank still prevailing on that fourth of the map, and the presence of finished pieces in the north and south-east is not much compensation for that fact. On the other hand we set against the drawback caused by this scattering of the work from year to year, and consequent delay in publication of the map, the fact that the knowledge gained in these distant regions has materially conduced to a clearer grasp of certain of the phenomena presented nearer home. It is of course urgent, for many public reasons, that as large a portion of the map as possible should be published at an early date, but naturally one would like to see the next part which may be issued form a definite and utilisable section of the whole.

Appendices II. and III. give in detail the results obtained by the Assistant Geologists in the Transkeian Territories. Of course work carried on in a new region so far removed from those already dealt with, could not at once be so speedy or so certain as that done in direct continuation of areas already known. Fortunately the unmistakeable Dwyka Conglomerate occurs in the Transkei, and no better geological bench-mark could be desired. It is easily possible thus to separate the Karroo rocks above the Dwyka, from the older Palæozoic quartzites and sandstones, though any nearer subdivision may have to be more or less tentative.

One interesting feature of the trip was the opportunity afforded for an investigation of the richly fossiliferous Cretaceous rocks, named on Mr. Dunn's map the " Umtamvuna Beds," and originally described, almost fifty years ago, by Messrs. Garden and Baily. Mr. Anderson has in Natal also been working at the Cretaceous Beds of that colony, and informs me that he has found the same richness in fossil contents as prevails in Pondoland. The section of Appendix II. devoted to the Cretaceous rocks gives the main facts discovered last year.

Igneous rocks are an important feature in the geology of the Transkei. They apparently belong to the same series of intrusions as appear in the rocks of the Karroo. The so-called Transkei Gap was found by Messrs. Rogers and Schwarz to be due to the erosion of a coarse-grained dioritic dyke. Many of the details will be found in the Appendix on the Kentani Division.

As this is the last annual summary of progress which I shall have the honour of preparing in connection with the geological survey of the Colony, I may be permitted to place on record my high appreciation of the work done by my colleagues Messrs. Rogers and Schwarz. Often left for months alone in the field, they have never failed to display the utmost enthusiasm in the work of the survey, and have spared neither time nor trouble to make the result as valuable as possible. It is a regret to me that circumstances should have prevailed to make what was meant to be a temporary arrangement exist for seven years, and that there should be such result as there is to show, must be placed entirely to the credit of the two Assistant Geologists, to whom I personally owe a deep debt of gratitude for the ready manner in which they have accepted the position and carried on difficult work without that support which should have been more often available from me.

There is also something more than regret in my mind that my connection with the survey should end while yet we have made little more than a beginning. During the past seven years we have had little experience of normal times, for pestilence followed the dispeace of the raid, and war the pestilence. The future must contain brighter days for the geological survey, and I hope I may be able to resume in some form or other my connection with a work of such interest and importance.

GEO. S. CORSTORPHINE,

Director of the Geological Survey.

APPENDIX I.

REPORT ON A JOURNEY FROM SWELLENDAM TO MOSSEL BAY.

1901.

A. W. ROGERS AND E. H. L. SCHWARZ.

REPORT ON A JOURNEY FROM SWELLENDAM TO MOSSEL BAY,

1901.

A. W. ROGERS AND E. H. L. SCHWARZ.

During March and April of this year, parts of the country between Swellendam and Mossel Bay were re-visited, with a view to making additions to and corrections of the geological map already constructed. The extension of the Cape Central Railway from Swellendam to Riversdale made it probable that much fresh information regarding the Uitenhage Series,[1] would be obtained from cuttings along the new line; and further evidence of the nature and distribution of the rocks named "surface quartzites" and "ironstone gravels" in former reports was desirable. Some fresh facts regarding the older rocks of the district were noticed, especially to the north of Mossel Bay, but no further separation of the Bokkeveld and Witteberg Beds of the Ruggens could be attempted.

On Hagel Kraal, a farm about eighteen miles north-west of Mossel Bay, a triangular area of micaceous slate, or phyllite, was found lying between the Table Mountain Sandstone on the north-west and the conglomerate of the Uitenhage Series on the east and south. The dip of the slates is nearly vertical, and the strike about east and west. The Table Mountain Sandstone to the north-west of the slates has a south-easterly dip, but the actual junction of the two rocks was not seen. It is probable that there is an overfold in the sandstone here, as between the Robinson Pass and the village of George, where it dips south under the Malmesbury Beds and granite.[2] The Hagel Kraal slates resemble some of the less micaceous varieties of phyllite met with in the George Division, such as those exposed by the road-side between Blanco and the Montagu Pass. They may be classed with the Malmesbury Beds.

An opportunity occurred of examining the curiously shaped hill named Bottels Kop, situated some ten miles north of Mossel Bay. It is part of a small area of a brecciated quartzite contain-

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(¹) As will be explained later, the term Enon Conglomerate used in former Reports to include all these rocks in the districts of Swellendam, Mossel Bay and George, has been abandoned on account of its inaccuracy.

(²) See Annual Report, Geological Commission for 1898, p. 60.

ing a few small pebbles of white vein-quartz. The hill is conical in form, with three crags at the summit, which give the name to the hill; one of the crags is a large mass of the quartzite supported upon a pillar of smaller diameter made of the same material. The rock weathers rather readily to a sandy mass, and the sides of the hill have much the same appearance as those composed of the white conglomerate of the Uitenhage Series. Parts of the quartzite are slightly micaceous, and have a somewhat schistose character. The bedding is obscure, but some divisional planes, probably those of bedding, seen in the crags on Bottels Kop, have a dip of about 15 degrees to the south Several quartz-veins of small dimensions traverse the quartzite. The area occupied by the quartzite is roughly triangular; on the north side the rock is bounded by the gneissose granite which extends from Brandwacht to the Great Brak River, and on the south-east and south-west sides the conglomerates of the Uitenhage Series overlie it. The junction with the granite was not seen, as a tract of ground without any outcrop, some three hundred yards in width, separates the nearest outcrops of the two rocks; the correlation of the Bottels Kop quartzite with the other rocks of the district is therefore a matter of some uncertainty. In the presence of white quartz-pebbles and the great thickness of the quartzite, it resembles the Table Mountain Sandstone, which is seen on Hartebeest Kuil, about eight miles to the south-west; but the Table Mountain Sandstone is generally a much more compact rock than that of Bottels Kop. On the other hand, there is no mass of quartzite of similar thickness known in the Malmesbury Beds of Mossel Bay or George. The micaceous quartz-schist of George, to which the Bottels Kop rock has a certain resemblance, forms bands, probably under 100 feet in thickness, lying between phyllites, and is different lithologically from the latter. On the whole it is more probable that the rock of Bottels Kop belongs to the Table Mountain Sandstone than to the Malmesbury Series. From the position of the conglomerate and clays of the Uitenhage Series, forming the hills to the east, west, and south of Bottels Kop, and rising to a greater height than it, it is certain that the Bottels Kop quartzite was once entirely buried under them, and has again become a hill owing to exposure by denudation. It is probable that the present form of the hill has not since its reappearance been materially altered by the weather, and therefore that the rock composing the hill has been subjected to percolating surface water for a very long period; this may to some extent account for the friable character of much of the rock.

Gneissose granite crops out along the stream from Kievits Kraal, and is a red rock containing biotite.

To the north-east of Herbertsdale the Table Mountain Sandstone of the Langebergen extends about four miles further south than was thought when the district was first examined. Outcrops of the rock immediately south of the mountains were met with in the steep kloofs which intersect the flat-topped hills; these latter are capped with the quartzite and other deposits which will be described later, and in general appearance resemble the hills cut out of the Uitenhage Series lying further south. On the eastern part of the farm Lange Fontein just west of the Table Mountain Sandstone described above, there is a small patch of slates, which, although no fossils were found in them, can be regarded as belonging to the Bokkeveld Series, as the Table Mountain Sandstone dips under them, and in lithological characters they closely resemble the Bokkeveld slates of the Ruggens. On the north, west, and south sides the slates are covered unconformably by the beds of the Uitenhage Series. This outcrop of the Bokkeveld Beds is separated from the nearest outcrops of the phyllites of the Malmesbury Series by a distance of about six miles. The dip of the Table Mountain Sandstone varies very greatly at different spots between the younger and older formations, but the close survey of that part of the district necessary for making out its true structure could not be made. It is not improbable, however, that the Bokkeveld outcrop of Lange Fontein is directly connected with that north of Aasvogel Berg, below the unconformable covering of the Uitenhage Series. The projections of the Table Mountain Sandstone southwards from the Langebergen between Lange Fontein and Hagel Kraal may extend under the Uitenhage Series and meet the tongue of the same rock which stretches northward from the east end of the Aasvogel Berg area as far as Hartebeest Kuil. If this bridge of sandstone connecting Aasvogel Berg with the Langebergen exists, it differs from the somewhat similar, but much larger connection between the Langebergen and Zwartebergen described in the Annual Report for 1898 (p. 60), by the fact that rocks of pre-Table Mountain Sandstone age occupy all the ground (omitting the Uitenhage Series) between the two ranges east of the connection; while in the case of the district north of the Langebergen, the ancient rocks are brought to the surface only immediately south of the Zwartebergen.

The maintenance of the general trend of the Langebergen throughout the Riversdale and Mossel Bay Divisions, in spite of the great change of structure along the southern foot of the range between Lange Fontein, where the sandstone dips under the Bokkeveld Beds, and Hagel Kraal or the Robinson Pass, where the dip of the sandstone is reversed and apparently dips under the Malmesbury Series and granite, is very remarkable. It seems to point to some former special conditions of denudation in the country east of the place where the change in structure occurs. This country is now a shelf between the Langebergen and the coast, deeply trenched by the rivers flowing from the mountains but unbroken by hills due to folds in the rocks, these having been planed down to a more or less uniform slope irrespective of their lithological or structural characters. Part of the reduction of the country was brought about before the deposition of the Uitenhage Series, but the inequalities were filled in subsequently by these rocks, and the present form of the coastal shelf is independent of their distribution ; the Malmesbury Beds, granite, Table Mountain Sandstone, and the soft clays and conglomerates of the Uitenhage Series have alike been planed down to a common level.

Near the village of Swellendam there are several small sections of reddish gravelly conglomerate seen in the ditches by the roadside. They are particularly noticeable along the first two or three miles of the main road to Heidelberg. The pebbles are of slaty shale and impure sandstone, derived from the Bokkeveld and Witteberg Beds of the neighbourhood. The surface of the country generally is covered with gravels, largely made of Table Mountain Sandstone pebbles and boulders, and at the time of our previous examination of the district we took the gravels along the main road to be recent gravels · At a bore-hole sunk at the Swellendam railway station, however, a thickness of 350 feet of conglomerate was passed through, and the boring was stopped before the underlying rock was reached.[1] The core shows the rock to be a conglomerate of rounded pebbles of slate, shales and micaceous sandstone, with a matrix of red and greenish sandy clay. Near the bottom of the hole a boulder of micaceous clay-slate, 7 ft. in diameter, was pierced, which was probably derived from the Malmesbury Beds lying north of the Worcester-Swellendam fault ; with the exception of this boulder, all the pebbles may well have come from the Bokkeveld and Witteberg Beds, and no fragments of Table Mountain Sandstone were met with. The thickness of this conglomerate, and the character of the pebbles and matrix clearly show that it belongs to the series of conglomerates, sandstones, and shales which we have described in former reports under the name of Enon Conglomerate, following the nomenclature of Mr. Dunn. The knowledge gained by the boring at Swellendam station enabled us to separate more certainly than before, when we had only small exposures in ditches to go by, the recent gravels and surface rubble from the conglomerates belonging to the Uitenhage Series. The latter were found to form an oval patch of ground between Distal's Fontein, on the east of Buffeljagt's River, and the village of Swellendam, an area about nine miles in length from W.N.W. to E.S.E. by four in width. Practically the whole of

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(1) Our thanks are due to Messrs. Saunders and Oakley, of Cape Town, for placing these facts at our disposal and allowing us to examine the core from this borehole

this area is covered by recent gravels or surface quartzites, and with the exception of a steep bank overlooking the alluvial plain on the east side of the Buffeljagt's River below the bridge, the conglomerates of the Uitenhage Series are only seen in artificial sections. In a shallow pit near the Swellendam station the conglomerates are seen to contain thin beds of sandy clay; these beds have no considerable extent, but thin out rapidly; they dip to the E.N.E. at an angle of about 15 degrees. Cuttings on the new railway line between Swellendam and Buffelsjagt's River have laid bare the conglomerates at a few spots. At one of them about five miles from Swellendam, in which white sandy clays are interbedded with conglomerates, the conglomerate is largely made of Table Mountain Sandstone pebbles, like the Honigklip's Kloof rock. This section is the only one yet found in the Swellendam Division in which the conglomerates of the Uitenhage Series are composed of pebbles of Table Mountain Sandstone. There is often difficulty in deciding whether any one exposure of conglomerate belongs to the Uitenhage Series or to the overlying recent gravels. This difficulty is of course greatest in the case of an exposure which is too small to allow bedding or deposits of different character to be detected if present. One very useful criterion exists, however, in the presence in many of the recent gravels of worn fragments of the surface quartzite which frequently caps the hills composed of the Uitenhage Series; this quartzite is of very much later origin than the Uitenhage Series and separated from it by a strong unconformity. Even small fragments of it can be readily distinguished in the field from any other quartzite known to occur in this country, so that the presence of boulders of this rock in a bed of gravel is a proof of the recent age of that gravel, and clearly separates it from the Uitenhage Series.

To the east of Buffeljagt's River red conglomerates, composed of pebbles of slates and sandstones, derived from the Bokkeveld and Witteberg Beds together with a few which may have come from the Table Mountain Sandstone, embedded in a red sandy clay, are seen on the steep slope of the plateau, which has been cut back by the river at no very distant period.

As to the form of the surface on which these conglomerates and sandy clays rest there is not much evidence; that their western limit is probably a cliff-like wall of considerable height is shown by the occurrence of a depth of at least 350 ft. of conglomerate at the Railway station, while about half a mile to the west, just west of the main street of Swellendam, rocks belonging to one of the older formations crop out considerably above the level of the station. The exact position of the boundary between the two sets of rocks is not observable, as alluvial deposits overlie it. That a cliff-like boundary exists at Swellendam is quite agreeable with what has been noticed elsewhere, at spots where the actual junction is seen, such as the left bank of the Lang Touw River, about a mile below Herbertsdale. Along other parts of the boundary it is impossible on the present evidence alone to decide upon this question.

The area occupied by the Uitenhage Series near Swellendam appears to be isolated. It is certainly cut off from the similar rocks in the west near Ashton, which lie some 25 miles away, while between it and the Heidelberg basin, which commences near Slang River 15 miles from the eastern limit of the Swellendam outcrop, the older rocks crop out at several points. A narrow connection, however, between the two may possibly exist and may have escaped detection owing to concealment under superficial deposits. When examining the new sections in the Heidelberg basin, we found that the rocks had undergone much more disturbance than we formerly thought, and the same may be the case at Swellendam, though it is difficult to regard the Swellendam basin as due altogether to earth-movement of post-Uitenhage date. Looking at all the evidence, it is probable, therefore, that the deposits of the Uitenhage Series were laid down in a pre-existing rock basin, the origin of which is as yet unexplained.

In the Heidelberg basin there are many fresh sections opened up along the line of the Cape Central Railway from the watershed between the Doorn and Klein Doorn Rivers and Riversdale. The examination of those cuttings has revealed three important facts,—the predominance of sandy clays and shales over conglomerates in this basin ; the considerable disturbance of the rocks ; and the wide distribution of the *Estheria*,[1] which we had formerly obtained only from the immediate vicinity of the village of Heidelberg, and on the bank of the Spiegel River.

In the railway-cuttings a sandy clay-rock is the most abundant. It is grey in colour, sometimes laminated so as to be a shale, but often forming beds up to three feet in thickness. There are frequent intercalations of conglomerate sometimes seen in the sections as more or less lenticular beds, often only a few inches thick and a few feet in length, but sometimes of irregular form and many feet thick. On the south side of the Klein Vette River, about six miles west of Riversdale, there is a section on the railway through a mass of conglomerates and sandy clays. The beds of conglomerate often lie on an unevenly eroded surface of clay or sand, and their upper surfaces are irregular, as if the conglomerate had been deposited in heaps, or had been subjected to contemporaneous erosion, and the resulting depressions filled in with material similar to that below the conglomerate. Phenomena of this nature were observed on the line at several spots between Heidelberg and Riversdale, and clearly point to the deposition of these rocks in water in which strong currents prevailed.

Many sections on the south side of the Doorn River (Heidelberg) show thicknesses of ten feet of laminated sandy clays without any admixture of conglomerate. Away from the railway cuttings it is always difficult, and often impossible to decide upon the nature of the rock underfoot, for the surface is generally gravelly, and the pebbles may or may not come from the rock just below the soil ; but it is certain, from an examination of the railway sections, that the general presence of pebbles in or on the soil gives one a greatly exaggerated idea of the extent of the conglomerates. The weathering of a thin bed of conglomerate of which the pebbles, or the larger ones, are left on the surface, while the sandy or clay matrix is washed away, leaves a covering of pebbly ground overlying clay or shales.

The conglomerates in the area dealt with are by no means confined to the lower portions of the Series. The general dip is between north and east. The beds of conglomerate seen in a kloof, near the main road about two miles west of Heidelberg, overlie the clays and shales exposed in the railway cuttings south of the Doorn River, for all the dips observable in that neighbourhood are northerly in direction. To the north-east of Heidelberg also, the conglomerates of the upper part of the Spiegel River overlie and dip away from a considerable thickness of shales which are exposed at various spots between the farm Spiegel River and the main road. At Cape St. Blaize, where the Uitenhage Series is represented by a hard sandstone resting upon a denuded surface of the Table Mountain Sandstone, which here dips steeply southwards, there are only a few inches of breccia at the base ; and westwards along the coast at certain places there is no breccia or conglomerate seen at the bottom of the Uitenhage Series, which are more clayey than at Cape St. Blaize.

The valves and impressions of *Estheria*[1] similar to those which were first found on the hill north west of Heidelberg, occur in several of the cuttings on the railway line between the Doorn River and Riversdale.

In a cutting at the place where the line enters the Doorn River Valley from the south-west there is a section through thin-bedded sandy clays containing *Estheria* ; there are concretionary layers of carbonate of lime and iron with "cone-in-cone" structure, and also thin layers of gypsum. This section is interesting also in showing two small faults, one an overthrust along which the beds have been displaced three feet, and the other a small normal fault. Several small faults were met with in the cuttings in the Doorn River valley but none of them shifts the beds through a distance as great as the height of the cutting. The dips in these cuttings reach 30° and are towards N. 20° E.

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(1) Some specimens of the *Estheria* obtained during a former examination of the Heidelberg Division were placed in the hands of Prof. T. Rupert Jones, who found them to be a new species which he named *E. anomala* See Geologica Magazine, 1901, p. 350.

In the village of Heidelberg the hill on which the Magazine stands has been excavated to make room for the railway station. The rocks excavated are clays and sandy clays. *Estheria* is abundant in them, and also a small Ostracod with smooth valves; fragments of indeterminable plant remains and a lamellibranch like *Psammobia* were also obtained in the same beds. Clays and sandy clays, with *Estheria* like those of the Doorn River Valley and Heidelberg were seen near the railway bridge across Spiegel River and also in the Vette River Valley about eight miles from Riversdale.

The succession of beds of the Uitenhage Series in these districts is very different from that in the Uitenhage Division. In former reports[1] dealing with this series outside the Uitenhage Division the name Enon Conglomerate was used to include all the deposits; the reason for this was that the term Enon Conglomerate had come into general use through Atherstone's descriptions and the maps of Mr. E. J. Dunn, and we had little knowledge of the relationship of these rocks to those of Uitenhage. The examination of the latter locality made during 1900[2] gave much information on the subject, and leads us to suspect that the rocks till now described as Enon Conglomerate in the west, are the equivalent of a considerably greater part of the Uitenhage Series than that division of it. Atherstone gave the name Enon Conglomerate to the red conglomerates at the bottom of the Series in the Uitenhage Division. These rocks comprise little else than conglomerates, the overlying sandstone and plant-bearing shales being very properly separated from them by Atherstone under the names of Zwartkop's Sandstone and Wood Bed, while to the overlying marine beds Atherstone gave the names "Lias Marls" and Dunn called them Sunday's River Beds. In the Report for 1900[3] it was stated that marine fossils were found in parts of the Enon Conglomerate, and that it seemed probable that this Conglomerate in different localities should be regarded as corresponding to various portions of the Uitenhage Series, rather than as a definite and limited division, always older than the Wood Bed and Sunday's River Beds. Both in the Sunday's River Beds at Uitenhage and in the conglomerate of Plettenberg's Bay *Trigonia conocardiformis* is found, which is good evidence that the rocks in these localities were formed at about the same time. The *Trigonia* has not been found west of Plettenberg's Bay, but the rocks of that locality are so similar in nature and geological position to those further west that there can be no doubt that they all belong to approximately

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(1) Annual Report, Geological Commission for 1898, pp. 61, 78 and 84; Annual Report, Geological Commission for 1899, p. 61.

(2) Annual Report, Geological Commission for 1900, pp. 1-18.

(3) Annual Report, Geological Commission for 1900, p. 5.

the same period, although no palaeontological evidence can be brought forward at present to prove it.

During the re-examination of the Series in the southern districts, the point that we noticed particularly was, as already stated, that the conglomerates form a smaller proportion of the whole Series than we thought was the case, and also that bands of conglomerate are interbedded with, and overlie the plant-bearing shales of Heidelberg and Herbertsdale, which were probably formed under conditions similar to those which prevailed in the Uitenhage Division during the formation of the Wood Bed.

The *Estheria* which is so widely spread in the shales of Riversdale has not yet been found in the Uitenhage district, nor has any species of plant been found to be common to the two districts.

As we have seen, the conglomerates and shales are frequently found to dip at considerable angles and are also faulted, so that they do not lie in the positions in which they were formed. It is very probable that the disturbances they have been subjected to have not been sufficient to obscure to any great extent the form of the surface upon which they were deposited. It is practically certain for instance that the conglomerates of Swellendam were formed in a deep hollow, the outlet of which has not yet been found, and that the Langebergen rose to a greater height above the hollow than above the present valley bottom; similarly, in the districts further east, the same range towered above the basin in which the conglomerates and shales of Riversdale and Heidelberg were being laid down. From the observable evidence of the great denudation which took place before the deposition of the Uitenhage Series in these districts, and from the presence of pebbles of Table Mountain sandstone in the conglomerates, we know that this sandstone was exposed during the deposition of the latter; that the great complex fold of the Langebergen was also in existence then is proved by the relationship of the Uitenhage Series to the folded rocks on which it rests. Some further movement along the old east and west lines of weakness may have affected the relative height of the crest of the Langebergen and the country immediately south and north, and may account for the observed dips and dislocations in the Uitenhage Series; but it is not probable that the form of the mountains has been materially altered by earth-movements since the beginning of the deposition of the latter. The only forces which have altered considerably the form of the range are those of denudation; since at the latest the Uitenhage Series is regarded as of Lower Cretaceous age, and there is no evidence to show that the Langebergen were ever completely buried under that series of rocks, it is obvious that the mountains must have been very considerably reduced in height during the time which has elapsed since Lower Cretaceous times. We may conclude from this that the country in which the Uitenhage Series was deposited was extremely rugged and that the declivities around the areas of deposit were very great. The great excess of the materials derived from the mountains through the agents of denudation over the amount which the rivers draining the area were able to carry away, gave rise to the deposits we are now dealing with.

SUPERFICIAL DEPOSITS.

The cuttings along the new railway have given us a better knowledge of the relationship of the recent gravels and quartzites to the older rocks, and to the drainage of the country than we had before. The recent deposits were briefly described in the 1898 Annual Report, p. 51, and three varieties were distinguished. 1st. The Genadendal type, consisting of boulders cemented together by a ferruginous matrix; 2nd. the Napier type consisting of a sandy ironstone; and 3rd. the Zwartklip type consisting of fresh-water quartzite or burr-stone. These three varieties were described as lying upon an old plain which was afterwards cut into by river channels to form the hilly country of the Ruggens. It was impossible to decide whether this plain was due to marine planation or whether it was just a levelling of the ground owing to the rivers having cut down to near sea-level, and the gravels in themselves afforded no conclusive evidence either way. In the following description it will be seen that the typical gravels on the tops of the hills grade into gravel plateaux which were undoubtedly formed by rivers, so that a definite advance has been made in understanding the formation of the Ruggens and the gravel caps.

On the west of Swellendam village there are three flat-topped hills covered with gravel, having a slight slope to the south. They lie between the streams which run down from the mountains, and overlook the valley of the Keurboom's River which comes from the west; on the south of the Keurboom's River the hills are not capped with gravel. The westernmost is the smallest, the next, larger, and the third, lying immediately to the west of Swellendam village, is divided into two, a small patch lying much nearer the mountains than the rest. On the opposite side of the valley in which the village lies, there is again another similar flat-topped hill which is practically part of the gravel-covered plateau to be described shortly. The gravel in these hills is not anywhere shown in section, and on the surface it seems to be made up of large blocks of Table Mountain Sandstone which are more of the nature of fallen blocks than of boulders carried by water, These hills are probably the remains of a once nearly level surface covered by a continuous sheet of boulders and débris derived from the mountains.

About three miles to the east of Swellendam there is a ridge in a similar position to these gravel-capped hills, but here the cap is made of hard burr-stone with only scattered fragments of foreign rocks. The ridge crosses the main-road at the highest point between the Cornland's and Buffeljagt's River valleys. From here the ridge runs south towards the Breede River with a more or less continuous capping of quartzite. The ridge towards the Breede River is bordered by a second plateau some 40 ft. below the summit; this is also covered with gravel and is found on the north side of the river to the east of Swellendam and can be followed as far as the Buffeljagt's River. Where the new railway cuts through the ridge there is a cap of the quartzite on top; on the east side there is a second patch of quartzite some 60 ft. below the first. This quartzite is somewhat more clayey than usual and in the lower part it grades into a yellow clay. It is horizontal and has all the appearance of being in its original position; the natural inference is therefore, that it is the product of the river lying to the east of the ridge, that is, of the Buffeljagt's River. This view is strengthened by the fact that the quartzite is separated only by a very slight rise from the plains covered with ironstone gravel which eventually merges into the gravel-covered plateau bordering the lower reaches of the Buffeljagt's River, and the north bank of the Breede River. The thickness of this lower bed of quartzite is about three feet.

On the main road the quartzite is seen on the south side where there is a quarry from which building stone is obtained. The rock is a cream coloured or yellow quartzite with a certain proportion of clay. In the lower layers the rock has the appearance of a yellow burnt brick, but on the surface there appears to have been a hardening probably by deposition of silica between the grains of the rock. As a rule the rock seems homogeneous, the quartz-grains of which it is composed being too minute to be visible to the eye, but gaps and irregular cavities are frequent, usually with deposits of iron oxides; there are also small pebbles or grains of vitreous vein-quartz, and in places a few pebbles of Table Mountain sandstone and other quartzites occur. On the opposite side of the main road, and between it and the road going down into Appel's Bosch, there is a thick development of the quartzite, the lower parts of which grade into a white clay. The thickness of these caps is here not less than twenty feet.

The main gravel plateau is found along the north side of the Breede River from the east side of the Cornland's River to the west side of the Buffeljagt's River and is thus on the outside of the bend of the Breede River which here turns from a general easterly course to a southerly one. The height of the plateau is from 100 to 120 ft. above the alluvial flats along the river. On the west of Swellendam it is cut in Witteberg Beds, on the east in Uitenhage Beds, the latter consisting mostly of red conglomerate composed of slate and sandstone pebbles; on the north the plateau is bounded by the ends of the foot hills of the mountains, and on the south the plateau is cut into a series of amphitheatres overlooking the Breede River, and having steep sides and level floors filled in with alluvium and covered with gravel and bush; in one of these amphitheatres a race-course has been made. Down the centre of the plateau there is the ridge of quartzite-capped hills mentioned above, but towards the south the difference of level between the plateau and the top of the ridge becomes less and less till the southernmost block of quartzite lies actually in the plateau. The gravel-covering consists of rounded boulders of Table Mountain sandstone stained with brown iron oxide, and often accompanied by deposits of ironstone and ironstone-gravel, similar to the laterite of the Cape Flats. Near the Buffeljagt's Railway Bridge the line from Swellendam crosses the gravel plateau which is here covered with great débris-blocks of Table Mountain Sandstone. There can be little doubt that these blocks are merely those that have fallen down from the mountains, and have been carried for a considerable distance over the gently sloping plateau perhaps by mud-rushes or rain-bursts. The large blocks are frequently four feet in diameter, and have sub-angular edges and corners. The extent of plateau covered in this way with débris is some two or three square miles and lies three miles distant from the Breede River and four miles from the mountain slopes; it is of the same nature as the caps of the hills south of the Keurboom's River near Swellendam. On the east of the Buffeljagt's River there is a further stretch of plateau ending on the north-east and south sides in the ordinary hills of the Ruggens, and on the west terminated by a steep slope, some 100 ft. high, overlooking the Buffeljagt's River. The covering is mostly composed of brown boulders of sandstone.

The conclusions to be drawn with reference to this plateau are:—1st. That it is of the same nature as that out of which the Ruggens was cut, owing to the similarity of the quartzites found in each; 2nd. That the plateau was formed by the Breede River and its tributaries either when there was a barrier in its lower course stopping the flow of water, or more probably when the sea-level was only slightly lower than the plateau; and 3rd. That the nature of the deposit on the plateau, whether of the one particularly described or of the Ruggens is dependent on the local conditions; near a mountain range the deposit contains large numbers of fallen blocks, further away from the mountains, the deposit may be of water-worn boulders gravel, fine sand, limno-quartzite or burr-stone, clay or ironstone.

A very good example of the gravels is found to the east of Zuurbraak. The Groot Vaders Bosch stream runs due west under the mountains; cutting this drainage valley at right angles there is another which probably was the original line of drainage on the plain, that is to say, the Buffeljagt's River, now running south through the Tradouw Pass, originally continued in a southerly direction along a valley now occupied by the Riet Kuil's and Karnemelk's Rivers. The Buffeljagt's River when it comes out of the Tradouw Pass now turns abruptly west, and is a tributary of the Groot Vaders Bosch River. The assumption of a former north and south drainage line is necessary to explain the presence of the gravels with debris-blocks that cap the hills overlooking the Zuurbraak valley. On the south side of the Groot Vaders Bosch River, these accumulations, exactly similar to those west of Swellendam, must once have been part of a plain that was continuous with the slopes of the mountains, as the débris-blocks could not have rolled down the mountain and skipped over any considerable valley, such as the present east and west one that separates them from the present mountain slopes. Between this original drainage line, namely the Buffeljagt's as far as its junction with the Groot Vaders Bosch River, the Riet Kuil's and the Karnemelk's Rivers, and the valley of the Breede River, there is at present a region of gravel-capped hills forming a high ridge some 600 ft. above the level of the last-mentioned river; this ridge has a slope towards the sea. The materials forming the caps are of the usual kinds, creamy and yellow quartzites and ironstone gravels.

Along the Spiegel River east of Heidelberg there are good exposures showing the relation of the recent gravels to the Uitenhage Series; the gravels we formerly had an opportunity of studying rested on the ordinary slates of the Ruggens assigned to the Bokkeveld or Witteberg Series, and from their gravelly nature they might easily be mistaken for outlying patches of Enon Conglomerate; it is not till one sees the recent gravels resting unconformably upon the Uitenhage Series that one can appreciate to the full the difference between them. On the upper reaches of the Spiegel River, and on the west side of the river, there is a ridge stretching south from Amandelbosch Rug. The northern part of the ridge is made of Bokkeveld slates, but there is only a narrow zone of these, about half a mile wide, the southward continuation being made of red, white and green clays and shales with interbedded conglomerates, belonging to the Uitenhage Series. Perched on the top of the ridge are blocks of recent quartzite looking from a distance more like granite tors than rocks of aqueous origin. The rock is a conglomerate with a quartzite matrix. The soft nature of the material on which the quartzites rest causes a rapid under-cutting of the hard cap, and blocks are frequently detached and fall down to the river ; this is the reason why there are so few caps remaining on the ground occupied by the Uitenhage Series. Lower down and away from the mountain slopes, the rock becomes an ironstone gravel. Where the railway cuts across this ridge the crest is considerably lower than the original plain of the Ruggens, but is still some 200 ft. above the level of the Spiegel River ; in this railway cutting, the alluvium of this river is exposed 100 ft. above the level of the present bed and piled up against a steep bank of Uitenhage Beds. In this alluvium, which consists of yellow sand with beds of coarse gravel and boulders, there are several great blocks of hard creamy yellow quartzite, quite angular and with no traces of any water action, the largest block in the section is eight feet long by three feet wide ; another block exposed, surrounded on all sides but one with mud, is nine square feet in section. The presence of these blocks is due to the river having undercut a cliff capped with a bed of these quartzites, but it is interesting to note that at such an early date, when the river had not cut more than 100 feet into the plain, the quartzites were already hardened and compacted.

Very good sections of the quartzite lying upon the Uitenhage Series are laid bare in the valley of the Nauga River near Herbertsdale. The unconformity is strongly marked in a section on the left side of the valley, where the Uitenhage Beds are composed of conglomerates and sand, and dip south-west at an angle of about 20°. The hill is capped by a bed of sandy clay with conglomerate and quartzite on the top, in all about ten feet thick. The clay and quartzite is part of a large area of similar material widely spread over the hills between the Mossel Bay main road and the Langebergen, but we have not seen elsewhere such a clear section showing the relationship of the quartzite caps to the Uitenhage Series as in the Nauga Valley.

The presence of conglomerates on the hill-tops which must have been formed on a very gently sloping plain at a distance of some miles from mountainous ground, may seem anomalous, but the conglomerates of the Uitenhage Series very probably supplied the boulders and pebbles now found in the gravels on the tops of the hills, and the latter may have been derived from spots very close to their present positions.

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APPENDIX II.

GENERAL SURVEY OF THE ROCKS
IN THE
SOUTHERN PARTS OF THE TRANSKEI AND PONDOLAND, INCLUDING A DESCRIPTION OF THE CRETACEOUS ROCKS OF EASTERN PONDOLAND.

1901.

A. W. ROGERS AND E. H. L. SCHWARZ.

GENERAL SURVEY OF THE ROCKS.

IN THE

SOUTHERN PARTS OF THE TRANSKEI AND PONDOLAND, INCLUDING A DESCRIPTION OF THE CRETACEOUS ROCKS OF EASTERN PONDOLAND.

A. W. Rogers and E. H. L. Schwarz.

The Native Territories, including the Transkei, Tembuland, Griqualand East and Pondoland, occupy a tract of country between the Drakensberg and the sea, a distance of about 120 miles. On the sea-coast the Territories extend from the Great Kei River to the Umtamvuna River, a distance of 150 miles; the coast-line is remarkably straight, and trends in a north-east direction; the inland border of the Territories is irregular. The total area is 17,542 square miles.

The Territories can be divided into three classes of country lying in belts parallel to the coast. The first, and the one we shall be most concerned with in the following description, is the elevated coast plain, or rather a succession of coast plains that rise one above another like gigantic steps all along the coast. It has an average width of 30 miles. On the inland edge of this belt there is the watershed of the coastal streams, behind which the main rivers of the country have their basins; these are more or less circular and the contributary streams gather together behind the watershed, so that the principal streams have a straight course to the sea through the elevated coast plains and receive only insignificant tributaries south of the coast-belt watershed. The rivers that are of this nature are the Kei, Bashee, Umtata and St. John's. Their northernmost tributaries come from the slopes of the Drakensberg, and these mountains and the plateau at their foot make up the third or mountain-belt; the second or intermediate belt is made up of the country between the edge of the plateau and the coast-belt, and consists of extremely rugged country cut out into hills and ridges by the streams, and with mountain masses, composed of great laccolites of dolerite, occupying roughly a line near the inland limit.

The journey which afforded the notes for the following description was taken mostly on the coastal plain watershed, in fact all roads are carried along watersheds of some kind, as the valleys are so steep-sided, that it is impossible to proceed in a straight line from one place to another. The towns of Butterworth, Idutywa, and Umtata owe their existence to their being on the main water-shed along which all traffic must pass. The even line of the watershed is broken beyond Umtata by the deep gorge of the St. John's River, but is continued on the N.E. side, where we find Flagstaff, Magusheni and Bizana, placed nearly on the line. We visited all these places, and to get round the St. John's River we at first took the lower route, through Port St. John's, and in returning, we took the upper, through the intermediate belt of country, past Mount Ayliff, Mount Frere and Qumbu.

To understand the geology of this part, it is necessary to bear in mind the main structural lines of South Africa which are clearly shown on Mr. E. J. Dunn's map. The main lines practically form the end of a rectangle with the south-eastern corner cut off by the sea-shore. Thus, taking the Table Mountain Sandstone as an indicator, on the west, the outcrop runs approximately south from Van Rhyn's Dorp to Tulbagh ; from Tulbagh it runs east and is cut off by the coast between Cape St. Francis and Cape Receife. At St. John's, Pondoland, the Table Mountain Sandstone comes in again from the sea, the outcrop running at first somewhat east of north, and afterwards in Natal approximately north. The country to be dealt with in this report is that included in the south-eastern corner of the rectangle.

Along the shore, the main feature is that of a wide syncline with the axis dipping inland in a north-westerly direction. The axis falls somewhere in the neighbourhood of the Great Kei River mouth. Along the coast, on either side, one encounters lower and lower beds; on the south-west, starting with the Karroo Beds with *Dicynodon*, one passes down through the Ecca to the Dwyka, Witteberg, Bokkeveld, and Table Mountain Sandstone: on the north-east, the Witteberg and Bokkeveld are not seen and the Dwyka Conglomerate lies directly upon the Table Mountain Sandstone. On the south and west again, passing from the gently inclined Karroo Beds to the Witteberg and Bokkeveld one comes to the folded rim of the Karroo, and complicated crumplings mark the outcrop of the older rocks. On the north-east on the contrary, below the Dwyka, the Table Mountain Sandstone is lying flat and shows no sign of crumpling, although there is evidence of its having been elevated above the sea before Dwyka times, having sunk to a short way below sea-level in Dwyka times, and finally, having been raised to its present position above the sea. One of the most striking distinctions between the geological structure of the Native Territories and that of the western portion of the Colony is the want of folding in the rocks of the former. Owing to this there are no ranges of mountains bordering the coast as in the west, the sea-mists travel uninterruptedly inland, and the effect on the climate and vegetation is most marked. In the west, the mountains wring from the sea-breezes all their moisture, and inland the country is parched and dry, forming in fact the Karroo. In the east the country is covered with grass and forest for a very long way inland and the effect of the wet sea-breezes is felt as far as Naauwpoort.

In dealing with the rocks of the Native Territories, the greater proportion of which lie above the Dwyka Conglomerate, one finds the same difficulties that beset the course of enquiry in the west, namely, the gradual transition of one set of beds into another, and the absence of any hard and fast characters in the various stages by which they can be distinguished; one has to rely upon the sum of the peculiarities of any stage, and it often happens that one notices differences in the field which are real enough, yet when one comes to describe them in detail, the distinctions seem inappreciable; on the other hand, by taking only the salient features, as is done in the subjoined list, one makes a sharpness in the divisions which does not exist.

We can, with the above reservations, divide the rocks above the Dwyka Conglomerate, into the following stages, placing them in descending order.

(*a*) Kentani Beds: dark shales, weathering light blue and green, with a few sandstone bands.
(*b*) Idutywa Beds: blue and purple shales with white sandstones; reptilian remains.
(*c*) Umsikaba Beds: sandy muds and clays.

The Umsikaba Beds correspond to the Ecca Beds of the west, which are also very badly defined on the upper limit; above these should come Seeley's *Pareiasaurus* zone and then the *Dicynodon* zone, both of which are characterised by slight lithological differences in the west. The distribution of fossil reptiles, however, through the Karroo Series has not been worked out in detail, and what little we do know is insufficient to allow us to correlate zones in different places by means of them. It is possible that the reptiles had a long vertical range and that the same reptile may be found at one horizon at one place, and at quite a different one at another. We cannot therefore say that because small reptiles like *Dicynodon* occur immediately above the Umsikaba beds, that there is a gap in the succession in the east; it is evident, however, that the conditions of sedimentation were different in the east and west of the Colony.

The Kentani Beds occupy nearly the whole of Kentani, as explained in the Report on that division, except for the narrow outcrop of Idutywa Beds on the sea coast and along the north-east. There is so much dolerite intruded in these rocks that one is apt to overlook the sedimentary formations, especially as most of the sections occur on the vertical cliffs of the rivers, which are very often inaccessible. Along the main road near Toleni, however, a good idea of the sedimentary rocks can be obtained; they here consist of shales and thin sandstones with silicified wood in comparative abundance. A very common rock about here is a black flinty slate, one could almost call it a hornstone from its appearance and mode of fracture, but in hardness it is different; it has on the outside about ¼ inch of decomposed yellow material, inside the rock is blue-black with a silky sheen and conchoidal fracture. On the Kogha River, along the new road from Kentani to Willowvale, another good exposure of the sedimentary rocks is seen. Shales here seem to predominate and are dark coloured, blue-black as a rule, till weathered, when they become light blue. Towards the base there are some purple shales and massive beds of light blue sandstone with the peculiar spotting that occurs so commonly round Graaff-Reinet. In fact the whole of the beds here may be said to have a Graaff-Reinet "facies," by which expression there is meant to be implied a possibility of their being of the same age, the facts at our disposal, however, are too slender to enable one to say definitely whether they are so or not. The only fossils yet found in the Kentani Beds are silicified tree trunks; the largest we found was on the road near Toleni on the west side; it was standing upright in the shales and about 12 inches in diameter; the top was scored with wheel marks.

East of Idutywa one at once realises that one has to deal with a new group of rocks. Sandstone bands are very frequent and the shales are more brightly marked in blue and purple-red. The streamlets, instead of cutting a more or less continuous bed for themselves down the sides of the hills, here form a series of small waterfalls caused by the ledges of sandstone above which there is usually a level portion with hollows and shallow pools. The vegetation is also different, being dryer, and with a small amount of bush with abundant aloes. The sandstone is white or light yellow as far as one sees it on the surface, and is fairly loose in grain. At Idutywa and Umtata there are quarries in this rock which is used a good deal for building-stone and seems to answer its purpose admirably.

The limits of this zone of course have not been ascertained, but it seems to form a belt running in a north-easterly direction. We found it between Idutywa and Umtata and along the Kokstad road near Tsolo, at Qumbu and along the Umzimvubu River (St. John's). At Mount Frere one loses the distinctive sandstone bands, and further east the country gradually assumes the character of that occupied by the Umsikaba Beds. Along the Kentani coast this zone apparently crops out under the upper beds, and there consists of light yellow sandstones with calcareous nodules, red and blue shales, and blue-black hardened shales, as described more fully in the Kentani Report. On the west of the Embotyi Mouth to the east of St. John's, the same beds are brought down by folding and faults, and one finds here grey and purple sandy shales with reptilian bones of the *Dicynodon* type and also the blue-black hardened shales. The appearance of these rocks on the sea-coast is different from that of the rocks at Idutywa, but the weathering in the two cases is so different, the one being washed by the sea and the other disintegrating slowly from the effects of atmospheric agencies, that the two need not necessarily have been originally different. We assume them to be the same from their stratigraphical position.

Some good sections in this stage are afforded by the road-cuttings on the east of the Tina Bridge, between Qumbu and Mount Frere. The sandstone is markedly false-bedded and at some places the sandstone beds end abruptly with square ends, andon the same line there are beds of mashed up shale and clay-pellet conglomerate.

Externally, that is to the east of the last belt, there is a tract of country occupied by the Umsikaba Beds; rocks that are equivalent in positionto the Ecca Beds of the west, but are not lithologically similarly owing to differences in sedimentation. Whether we look at them at the typical place Umsikaba (Flagstaff) or at Libode or at Bizana, we find them of the same nature, a thick mass of clays, sandy in parts and but little hardened; on the surface they easily break down into ordinary tenacious clay, and when wet, "ball" under the feet of men and horses like the London Clay for instance. They are weakly bedded in banks of from three to six inches in thickness, and are normally dark-blue, but when exposed, decompose into a brick red mass, and form a deep chocolate-coloured soil. The lower beds are more shaly and more thinly bedded, often with rounded blotches of yellow iron oxide, like small wafers scattered over the surface of the beds; these blotches are very similar to those found in the lower Bokkeveld shales round Montagu, and are seen along the road between St. John's and Lusikisiki, and also near the Embotyi mouth below Lusikisiki. When altered by intrusion of dolerite, the Umsikaba Beds often become hardened into a rock which is black and rather like hornstone with the fracture of flint, but is not very hard; it is jointed along three planes so as to split up into small rectangular blocks which on exposure become rounded on their edges and weather concentrically, each block being made up of several shells, about half an inch in thickness, moulded round one another. When weathered these concentric shells readily break away and little pipes, three or four inches in diameter can be obtained having a square section with the corners rounded off, and look very much as if artificially formed of clay, and then sun-baked. Some very good sections of the rock in this condition can be seen along the road between Umsikaba (Flagstaff) and Puff-Adder, and also in the road-cutting just below the Tsala hills ; in each of these cases the rock underlies thick masses of dolerite.

It is very difficult to assign an upper limit to this series of beds as they gradually merge into the Idutywa Beds, above, and the country is very much broken up with dolerite sheets and dykes which cover a great deal of the sedimentary rocks. Thus between Magusheni and Mount Frere, a distance of between 30 and 40 miles, we pass from undoubted beds of the Flagstaff facies to ones very similar, but with one or two hard beds of sandstone; on the west of Mount Ayliff at Rode (Ghode) the sandstones are more frequent, and at Mount Frere are very apparent, though even here it is at present impossible to say definitely that the beds belong to the Idutywa facies.

Below the Umsikaba Beds comes the Dwyka Conglomerate lying unconformably on the Table Mountain Sandstone, but before describing these, it will be as well to discuss the igneous intrusions which are almost confined in the Territories to the outcrop of the overlying beds. Those in the underlying beds are insignificant compared with these.

The igneous intrusions form one series with the basic rocks that are found traversing the sedimentary rocks in the centre of the Karroo, these latter are connected in some way with the sinking of that centre to form the basin-structure which the rock systems now assume in the interior of the Colony, but the basic rocks in the Transkei are different in mode of intrusion to those in the west. From the very little that we know concerning the igneous rocks of the east of the Colony and Natal it is impossible to get any idea of the causes which led to their intrusion, but our present work enables us to establish, at any rate, the following distinction between the forces at work in the east and the west of the Colony. In the west the dolerite is intruded in thick sheets which are continuous for miles and miles, and are sometimes parallel to the bedding, sometimes cutting the bedding of the sedimentary rocks at a low angle ; in the south of the dolerite area the sheets dip north, in the north, south, conforming to the shape of the Karroo basin ; dykes connect the various sheets and occur plentifully throughout the region. The inference is that, here, as the centre of the basin sank, the once horizontal beds stretched on bending, leaving cracks which became filled in by dolerite from below, the latter no doubt exercising considerable pressure in forcing its way along, but the intrusion was unaccompanied by any manifestation of upheavals or disruption. On crossing the Kei River one at once notices a very different order of things. Here the basic rock occurs in laccolitic masses 500-800 feet and even more in thickness in the centre, and rapidly thinning out on the sides; where sheets do occur extending over any large area one gets patches of great thickness, and surrounding them, areas where the thickness is reduced to a few feet or less. Good examples of this are mentioned in the Report on Kentani in reference to the Manubi sheet. These local thickenings indicate that the dolerite at the time of its intrusion exerted a very great force, one sufficient to lift the covering of rocks in the places where the thickenings of the dolerite occur, and wherever one goes in the Territories one has this evidence of the igneous rocks having forced their way into the sedimentary rocks by their own impetus, instead of, as in the west, their having quietly followed lines already opened for them.

No difference in composition between dolerites in the east and those in the west have been observed, the occasional presence of micropegmatite is common to both in the east and the west. But we find in the east the dolerite grading off into diorites and even granite, the rock still containing some of its peculiar minerals, but altering by reason of the increasing quantities of quartz and of potash felspar. One long vertical double dyke of rock of the dioritic stage of acidity is found traversing the country between the Kei and Toleni bridge on the main road from the Colony to Butterworth. These weathering easily, have produced a series of east and west valleys and thence the trough thus formed is named the Transkei Gap; they are further explained in the Kentani Report. At Toleni Bridge itself, a dyke of this same diorite is seen cutting vertically across the dolerites and sedimentary rocks and running in an east and west direction. Still more acid varieties are found at Gonubi hill in Komgha and near Gqunqi in Kentani. From a petrographical examination of these rocks it seems probable that dolerite, diorite and granite came from the same magma; that the more basic, and therefore more liquid variety, was extruded first; then in order of acidity, the more acid varieties, which were more viscid and required a greater heat to keep them in a molten condition. With the small amount of field-work done in the Eastern districts it is premature as yet to speculate on the bearing these facts have on the general question of the origin of the igneous intrusions in these parts.

Along the banks of the Great Kei River, north of the bridge, there are some very fine examples of the laccolitic form of intrusion of the dolerite, but what strikes one at once is that the sedimentary rocks do not seem to have been arched up over the dome-shaped masses of igneous rocks; the contacts are not well shown, but it certainly looks as if the strata had disappeared in the space occupied by the igneous rock, and the ends of the beds seem to abut against the rounded contours of the dolerite, a fact which we again and again noticed throughout the Territories, and which was beautifully shown in the sections of actual contacts along the Kentani coast, On the south side of the Toleni River, near its junction with the Kei, there are two smaller rounded masses of dolerite one near the river level, the other somewhat higher, and in neither case do the sedimentary rocks show any disturbance. The Toleni shop is on top of the coastal plateau, and here the watershed has been eaten back by the Butterworth (Gcua) River the tributaries of which make a deep bay; at Ibeka a few miles east of Butterworth the watershed comes back to its usual line. All this country is covered with dolerite in the form of a sheet of varying thickness, the sedimentary rocks appearing only in small patches; a few hundred yards north of Ibeka shop there are more acid varieties of rock which appear to be connected with the dolerite of Ibeka itself. East of Ibeka, though we are on the actual watershed of the coastal streams, there is only a little dolerite, a thin sheet coming in about half-way between Ibeka and Idutywa; this shows that the dolerite played no part in the formation of the watershed, but that the course of the rivers was determined independently of them. At Idutywa one enters the region of the Idutywa Beds, and for some way there is little dolerite; two small sheets, one two feet the other one feet in thickness, are encountered on the Qunu River east of Idutywa, they are glassy and have baked the sedimentary rocks to a certain extent. Some small dykes are seen on the west side of the Bashee River, but on the east there is a great series of hills made of dolerite, about five miles long, extended in a north-north-easterly direction. Before reaching the top of the hill on the eastern side there are road quarries showing some good sections of the contact; the main mass of the dolerite becomes suddenly thin leaving a nearly vertical dome-shaped face, against which the sedimentary beds abut without disturbance; some lenticular dykes are intruded in them, evidently off-shoots of the sheet. The thin portion of the sheet passes underground in a northerly direction. Between here and Umtata there are some patches or lenticles of dolerite of great local thickness, but of very small superficial extent. A little east of Springvale there is a long dyke dipping 45° to the eastwards, striking, north of the road 10° W. of N., and south of the road, 30 E. of S.; this dyke is many miles in length. Between here and Umtata there are no dolerite outcrops, but a mile south of the town the Umtata River falls over a ledge of dolerite about 100 ft. thick, forming a fine waterfall; the river has excavated a beautiful amphitheatre, and on the west side especially, the dolerite has weathered in columns which stand up in picturesque positions. The sheet of igneous rock ends abruptly to the south east, but we were not able to make out whether this was due to faulting. East of the Umtata River we found a great deal of dolerite in sheets and dykes; at Libode there is a variety with a great deal of brown mica, and half way between Libode and Old Bunting a true granitic rock crops up in rounded masses, occupying only a small space. On the north-east of Umtata, the Tsitsa falls are formed in the same way as the Umtata falls, but here the height is some 370 feet, and two-thirds of this is a sheer drop over a vertical wall of dolerite. The lower third is made of shales, probably hardened by the dolerite, at any rate, with no vertical jointing, so that the water has cut a sloping surface across the beds ; on the Tina there are similar falls.

On the east of St. John's River, we traversed a very wide area covered with dolerite sheets and dykes. Lusikisiki, Flagstaff (Umsikaba), Bizana, Emfundisweni, Mount Ayliff, Mount Frere, all lie practically surrounded by dolerite ; we were unable to map out their distribution, but over this area the laccolitic masses of dolerite are very prominent and form the most striking features. The southernmost mass constitutes the Tsala Hills, north of Palmerton, two great blocks of dolerite standing above the plain, with steep sides, at places vertical, but unlike similar hills around Steynsburg for instance, one does not see in the neighbourhood hills capped with similar masses of dolerite. As one passes north of the coastal plateau, into the intermediate belt of country, these laccolitic masses stand up on all sides forming isolated mountain masses which have distinctive names such as Mount Ayliff, Mount Currie, Mount Frere. Mount Ayliff is really only part of a great mass of dolerite, this particular block being divided into several portions divided by high neks, but north of Mount Ayliff the Insiswa forms a compact mass with square faces turned to the south and west and sloping gradually to the north. The dolerite here is 400 to 600 feet thick. It is quite possible that it also formed one great laccolite with the Mount Ayliff mass, the two having been separated by the Umzimhlava River, but on the east side it dies out quite suddenly, and the high ridges on this side are riddled with small dykes and sheets, possibly off-shoots of the main mass.

The Dwyka Conglomerate was first met with on the road from Old Bunting to St. John's at the Umgazi River. On the south side one sees a steep cliff of the rock with the Umsikaba Beds lying conformably and horizontally above the conglomerate. The rock is an indurated till, weathering easily, and from the matrix one can easily obtain a number of well-scratched boulders quite typical of boulder-clay ; slate, quartzite, granite and atered basic rocks, diabase and amygdaloids, are the most common rocks composing the boulders. Further on, the road climbs a ridge in which the road-cuttings afford excellent sections of the boulder-clay. At the next river there is a cliff 150 to 200 feet high, very nearly perpendicular, composed of black unweathered Dwyka Conglomerate. From here one climbs the final rise on the road to St. John's ; the hill is made fo

Dwyka Conglomerate. On descending the cutting leading to the St. John's River, one sees some good sections of conglomerate and in several places, the road is taken close to the Table Mountain Sandstone which shows a clean-cut vertical face, evidently a fault-face; the fault runs about east and west. It is very difficult to understand the relationship between the Dwyka Conglomerate and Table Mountain Sandstone near St. John's, the maps are very meagre and it is impossible to plot the various features in detail, and without such plotting the elucidation of a complicated district like this is impossible. As will be described later, the Table Mountain Sandstone forms an inlier about 8 miles long, rising abruptly from the Dwyka Conglomerate and Umsikaba Beds that surround it on all sides, the inlier is cleft through its highest part which is likewise the centre, by a narrow gorge, on either side of which rise the Gates of St. John's.* The gorge is remarkably straight and is directed south-east, and hence the fault runs towards the gorge and possibly turns round and coincides with the south-west cliff which defines the Gate on that side. On the north-east side there is an exactly similar cliff, and a little Dwyka Conglomerate can be found running from the inland opening of the gorge towards the chasm, and opposite St. John's village there also is a ledge of Dwyka Conglomerate at sea-level under the cliffs, so that one possible explanation of the origin of the Gates is that a narrow strip of rock has been let down between vertical faults. The Gates now tower 1,200 ft. above the level of the river, and the top of the sandstone composing the narrow faulted strip must be some distance below sea-level, the water in the river being in places 50 ft. deep so that, allowing for weathering, the throw of the fault would approach 1,500 ft. The width between the wall of the cliff is 660 yards. It must be remembered, however, that the erosive force of the river is quite sufficient to explain the gorge without bringing in a rift fault, and that the evidence for the latter, though suggestive, is far from conclusive.

On the sea-side of the Table Mountain Sandstone next the sea there is also a high cliff against which abut the Dwyka Conglomerate and the overlying Umsikaba Beds, and perhaps on the west, representatives of the Idutywa Beds. The boundary of the Table Mountain Sandstone runs through the village of St. John's, the greater part of the village, however, being built on hard black shales and brown quartzites dipping steeply to the south-east. Some of the beds south of the village have obscure markings like the impressions of *Phyllotheca* and *Sigillaria*, but hardly plain enough to afford any guide as to the age of the rocks; at first we took them to be Witteberg Beds as they are somewhat like the rocks of that age near Port Alfred, but there is doubt now that they overlie the Dwyka Conglomerate. The form of the hills near the coast composed of these rocks is somewhat singular as they run parallel with the seashore and are very high, varying from 300-400 feet, and are sharp-crested, with a valley running immediately behind them; the gaps formed by the rivulets which have cut a passage to the sea and the abrupt sides of the hill-slopes make travelling difficult about here and quite impossible with vehicles. From the camping place at St. John's to Cape Hermes there is a sea-washed section of these rocks mostly consisting of brown quartzites, in one band of which we obtained some *Phyllotheca*-like stems; the extremity of the point is made of dolerite. On the inland side the rocks are much softer and are traversed by vertical dolerite dykes. On the coast to the south-west, on the west side of the mouth of the Bulola River, we found the same black shales with *Sigillaria*-like impressions and a good deal of black limestone in bands, showing admirable cone-in-cone structure; with the limestone there were also associated lenticles of iron ore.

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* The two highest peaks on either side of the river are known as the Eastern and Western "Gates," though the word gate should refer to the river-gorge.

On the north-east side of the St. John's River, there is a narrow belt of Dwyka Conglomerate, lying at the foot of the high Table Mountain Sandstone cliffs, which here trend to the north-east. The conglomerate is seen first on the landing place opposite the town, as a shelf extending a short way up the river and level with the sea at high water on the sea side, the conglomerate forms a small mound or hill forming a low counterpart to the Signal Hill or Mount Thesiger on the opposite side. On the north-east side of this there is a small rivulet, on the east side of the mouth of which there is a small exposure of carbonaceous shale softer than that at the Bulola River, which has been dug out in the hope of reaching coal. The outcrop is very small here, as there is so much debris from the high cliffs of sandstone above, enormous fallen blocks of which cumber the surface. Further along there is a small patch of black shale dipping south-east at a low angle, this is underlain by a thick mass of dolerite which breaks across the bedding and comes to the surface a little way to the north-east. From here the rocks along the coast are obscured by a great quantity of sand, largely composed of magnetite weathered out from the dolerite. After passing the sand, there are tabular masses of black shale dipping at a low angle to the south-east similar to the Bulola shales but here hardened by the intrusions of thin dolerite sheets, and thus enabled to stand out among the breakers; they are covered with sea-weeds, corals, oysters and other sea-beasts, and the many cracks and crannies on the rough surface conceal the octopus, ascidians and other delicacies which the Pondos eagerly seek for. The dolerite sheets vary from 10 inches to 100 ft. in thickness and give off interesting lens-shaped pieces which are wedged in between the beds of shale above or below and from some of which one can trace the connecting bridge of igneous rock between them and the parent sheet.

Some twenty miles along the coast north-east of St. John's there is again a cliff of Table Mountain Sandstone, formed by a fault-face trending east and west. Between this fault-face and the Port St. John's mass of Table Mountain Sandstone there is a stretch of country, composed of Dwyka Conglomerate, Umsikaba Beds and Idutywa Beds. The country once was a plateau raised some 1,000 ft. above sea level but owing to the easy weathering of the rock it is now cut into by the river channels and is a labyrinth of ridges and deep kloofs, covered in great part by forest and but little inhabited. The beds are so arranged that inland, along the road from St. John's to Lusikisiki, they are lying flat, and consist of Umsikaba Beds on the surface of the higher parts, but the Dwyka Conglomerate is found in the deep kloofs; towards the shore, however, the beds begin to dip in an easterly direction, and eventually the Idutywa Beds with fossils are brought down near the Embotyi Mouth. The bending of these beds has an important bearing on the nature of the fault-face, for had the younger beds been lying undisturbed at the foot of the cliff, it would have been quite legitimate to suppose that these had been laid down in the position they now occupy.

Beginning at this fault-face there is a band of Table Mountain Sandstone running parallel with the coast and varying from 12 to 15 miles in width. The inland edge of this is covered by Dwyka Conglomerate lying unconformably upon it; we saw no signs of glaciated pavements, but we found no good sections showing the junction of the two rocks. The band of Dwyka Conglomerate is narrow on the south-west; below Lusikisiki it begins just south of the village, and is three miles wide, to the east, by Bizana for instance, the belt broadens out to ten miles. The rock is the ordinary indurated boulder-clay, such as we found in Prieska or Calvinia, and is penetrated to a small extent by dolerite dykes and sheets.

The Table Mountain Sandstone of Pondoland occurs in the Gates of St. John's and also in the coastal strip which runs into Natal, where again Malmesbury Beds underlying it are exposed. In Pondoland the beds are lying flat with a very slight dip inland, that is, north-west. Even local folds are very rare, and these are monoclinal.

The St. John's mass is eight miles long and about five broad, extended parallel to the coast. It is divided into two by the deep gorge of the St. John's or Umzimvubu River. The western half is bounded on the north and south by fault-faces with a very considerable throw, between 1,200 and 1,500 ft. at least; on the west the sandstone passes unconformably below the Dwyka Conglomerate. The eastern half is bounded on the south by a fault running north-east and on the north passes unconformably under the conglomerate. The gorge separating the two halves may be a cleft already formed when the Dwyka Conglomerate was being laid down, or it may be due to a double fault letting down a strip of rock; or again it may simply be an ordinary channel cut by the river. The mass of sandstone has all the appearance of a "Nunatak," that is, a hill left standing in the course of a glacier which curved round it. On this supposition the St. John's Gates would represent the Nunatak which on the retreat of the glacier was surrounded by the morainal material piled up against the vertical sides of the cliffs; but though by these means we can explain some of the features of this neighbourhood, we cannot explain the high dips of the beds lying against the southern side. The fault-face to the north, again, might be held to represent the confining wall of the glacier were it not for the high dip of the beds.

The main body of the Table Mountain Sandstone is met with on the coast some 20 miles north-east of Port St. John's and a little south-west of Port Grosvenor. It forms a cliff running east and west, about three hundred feet high, and at the foot is the beach; over the edge of the cliff the rivulets pour their waters straight into the sea, and hence the name of this point "Waterfall Bluff." From here the fault-face runs inland to the west, the outline being slightly curved with the concave side outwards, that is, to the south. The length of the fault-face is about 15 miles, and the inland end of it passes under the Dwyka Conglomerate near the Umzimhlava River. The fault-escarpment is thickly wooded and is known as the Egossa Forest. It is indented by tremendous gorges, one, the Magwa, is formed by an insignificant stream rising south of Lusikisiki; at the junction of the Dwyka Conglomerate and Table Mountain Sandstone there is a small patch of forest out of which the river comes to fall a sheer 500 ft. into the gorge, the cleft commences abruptly and is about thirty yards across, continuing with only a slight widening for about a mile when the edge of the fault escarpment is reached, and the river enters the hilly low-lying country composed of Dwyka Conglomerate. This wonderful cleft is held in dread by the Pondos, and was formerly a place of execution, the victims being thrown over the edge, or blinded and allowed to walk over. It was here, also, that the last troop of elephants in the Territories was destroyed; they were being hunted by the Pondos and all went over the edge and were killed. There are several similar clefts, but the country is so thickly wooded about here that most of them are inaccessible.

The strip of Table Mountain Sandstone beginning at the fault-face runs north-east and varies from 12 to 25 miles in width. It forms three terraces, the lower one on the coast being about 200 feet high and sloping upwards to the foot of the first step or escarpment at about 500 feet above sea-level; the escarpment is about 300 feet high and the terrace above it rises about 200 feet to the foot of the next step, which is not so high as the first, and the level of the plain at the junction of the Dwyka Conglomerate is from 1,200 to 1,500 ft. above sea-level; the surfaces of the terraces form wide grass-covered plains running parallel with the coast. They are probably surf-cut, and were formed as the land rose, and are comparatively recent; the Dwyka and Cretaceous Beds were already faulted down into their present position at the time of their formation and were also cut into in the same way, but owing to their less resistent nature, they were cut back more than the Table Mountain Sandstone, and the lower terrace in the younger beds extended further inland than in the older sandstones. The cutting back of the younger beds is well seen at Waterfall Bluff, the fault-face extending about two miles into the sea beyond the younger beds, so that if the land was to rise to any considerable extent again, the new surf-cut terrace on the Table Mountain Sandstone would be two miles nearer the sea than that on the Idutywa and Umsikaba Beds. The sandstone is apparently horizontal throughout this strip except for a few small monoclinal folds near the coast on the north east. One such is well seen in the gorge of the Umzamba River a little way inland, and another is seen at the mouth of the Umtentwana River to the north-east of the former; the axis of these folds is apparently parallel with the coast and they make no alteration in the level of the surface.

THE CRETACEOUS ROCKS.

On the Coast of Pondoland there are some rocks containing Cretaceous fossils, many of which have been determined or described by Baily(¹) and Griesbach(²).

In Griesbach's paper the rocks are called the "Izinhluzabalungu deposits," from the caves of that name, but the locality given in the description of the fossils is "Umtamvuna River," a name adopted by Mr. Dunn for the Cretaceous Beds in the 1885 edition of his map of South Africa. It is unfortunate that this name has been used, as the rocks do not appear on that river at all. The first name "Izinhluzabalungu" (houses of the white men) used by Mr. Griesbach, is too awkward for general purposes. The rocks are frequently referred to in geological literature as the Cretaceous rocks of Natal, which is misleading, as although it has been known for some time that probably contemporaneous rocks do occur in that Colony, they have not yet been described, and in

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(¹) Baily and Garden, Q.J.G.S., XI., 1855, pp. 454—465.
(²) Griesbach, Q.J.G.S,, XXVII., 1871, pp. 53—72.

Griesbach's paper on the geology of Natal, the rocks appear under the heading "The Cretaceous rocks of South Africa." The only descriptions of their occurrence are to be found in Captain Garden's and Mr. Griesbach's papers; as a result of a more detailed examination of the country than that made by those authors, some additions to and corrections of their accounts are necessary. The rocks occur to the south-west of the mouth of the Umtamvuna River; near that river the rocks above low watermark are rather coarse quartzitic sandstones belonging to the Table Mountain Sandstone which stretches north-eastwards from the Magwa River to Natal; the Table Mountain Sandstone lies nearly flat at the Umtamvuna mouth, but at the mouth of the Umtentwana there is a small monocline with the sandstone dipping 15° towards the south-east. Along the shore nothing but sand with occasional outcrops of Table Mountain Sandstone was seen for a distance of from two to three miles from the Umtamvuna, but beyond that distance on the other side of the Umtentwana lagoon, the Cretaceous rocks are met with below the level of high tide; they form a flat, rough platform, laid bare for a hundred yards or more during low water at spring tide. Behind them the beach is made of sand which gradually rises into the bush-covered dunes. About a mile from the Umzamba mouth the Cretaceous rocks appear behind the shore, and above the level of ordinary high tide, in the form of a hard bank rising about two feet above the sandy beach, and covered by a loose calcareous tufa deposited by the water which has trickled through the overlying sand-dunes. The small bank of Cretaceous rocks is hollowed out below, where the rock is softer than in the upper part; towards the south-west the bank becomes gradually higher and higher, as far as the north-east end of the sand-spit at the mouth of the Umzamba River, where there are cliffs about 30 feet in height cut in the Cretaceous rocks, the upper part of which, however, is covered over by sand and vegetation. The rocks are composed of alternating bands of sandy calcareous clay and thin shell-limestones, with little sandy material in them; the shell-limestones are much harder than the thicker intervening beds, and stand out as prominent shelves, while the softer rock is more easily removed by the action of the waves and weather; the result is that the whole range of cliffs about a mile in length, presents a front carved out into shallow caves with horizontal floors and roofs, and of varying heights according to the thickness of the soft sandy limestone. The beds lie nearly horizontally, so that one thin bed may form the surface of the beach for many hundreds of yards. As one walks eastwards along the beach from the Umzamba end of the outcrops, one meets with slightly higher beds on the shore. On the south-west side of the Umzamba River the Cretaceous rocks again occur, and we followed them at low water for nearly ten miles along the shore towards the Umtentu River. They do not appear above the shore, although it is likely that if the sand were removed from some parts of the shore a bank formed of the Cretaceous rocks would be seen. Although we were unable to reach the Umtentu, and to determine the south-west limit of the Cretaceous outcrops, it is improbable that they extend so far as that river, for the form of the coast changes, and from a distance it appears to be made of Table Mountain Sandstone. At the Umsikaba Mouth some miles south-west of the Umtentu, the coast is made of Table Mountain Sandstone.

From the accounts given in Garden's and Griesbach's papers it is evident that the exposure of the rock between the Umzamba and Umtamvuna Rivers varies considerably from time to time. Garden notes that the rock behind the beach forms caves for 800 yards, but at the time of our visit the line of caves (those at the north-east end do not really deserve that name) certainly extended through the distance of a mile ; Garden also saw the Cretaceous rocks exposed at the extreme end of the left bank of the Umzamba, but now there is nothing but sand there. In neither of the two papers are the outcrops mentioned which we found below high tide level to the north-east of the larger caves ; these outcrops belong to the bed marked " b " in Griesbach's section. The actual junction of the Cretaceous rocks with the Table Mountain Sandstone was nowhere seen by us in this part of Pondoland, although we saw the faulted junction of some conglomerates and sandstones with the Table Mountain Sandstones, and as will be seen later there are reasons for thinking that these belong to the Cretaceous Series. Near the Umzamba River outcrops of Table Mountain Sandstone are met with at a distance of about 400 yards inland from the coast, and the distance decreases towards the north-east, so that two miles away the sandstone crops out on the beach. South-west of the Umzamba the breadth of the area occupied by the Cretaceous rocks does not increase, but appears to be nowhere more than about a quarter of a mile. On the right bank of the Umzamba the Cretaceous rocks can be seen for some 300 yards up the river from the mouth, but they retain their character as shelly limestones and calcareous sands throughout, and do not show any sign of an ordinary unconformable junction with the Table Mountain Sandstone ; it is very probable that the junction is a faulted one, and this suggestion is supported by the very straight boundary between the two rock systems, and the occurrence of the stratigraphically higher one at a lower level than the stratigraphically inferior system.

The lowest beds (corresponding to the bed "b" in Griesbach's section) visible during our visit were seen at low tide and consisted of coarse shelly and sandy rocks with pebbles of dark slates and coarse grits or sandstones ; there are numerous logs of fossilized wood, often silicified and bored by *Teredo*, and the worn bones of reptiles, amongst which some had the distinctive characters of Chelonian bones; sharks' teeth were also found in this bed; among the Invertebrates were *Ammonites Soutoni, Stangeri, Umbolazi* and *Gardeni*, a species of *Baculites;* gasteropods were represented by *Fasciolaria, Avellana* and *Chemnitzia;* lamellibranchs by three species of *Pecten, Inoceramus, Protocardium hillanum, Trigonia elegans, Pectunculus africanus, Arca natalensis* and *Cardium denticulatum.* Many of these shells occurred in a very fragmentary condition, and recognisable specimens were only obtained by searching through a considerable amount of rock. The *Inoceramus,* in particular, furnished a large quantity of calcareous fragments to the sand. The above invertebrate fossils are mentioned because they also occur at higher horizons in the Izinhluzabalungu cliffs, and were considered by Mr. Griesbach as characteristic of the higher beds only. There were many other interesting forms, such as *Nautilus, Baculites, Trigonia Shepstonei,* a large gasteropod belonging to the *Strombidae,* and a polyzoon in this bed. From the condition in which the bones and many specimens of the shells occur it is certain that they were rolled about in a shallow sea, or even on the beach itself, before being buried; the stronger forms, such as *Arca* and *Pectunculus* are frequently found with their edges rounded and all the projecting ridges worn off them, while delicate fossils are rare; some indeed, such as *Hemiaster* and *Cassidulus* which are quite abundant in the immediately overlying fine-grained deposits, are entirely absent. South-west of the Umzamba a precisely similar bed occurs below high water-mark for some eight miles along the coast, but there were stretches of sand which hid the rock, at frequent intervals. From this part of the outcrop we obtained Chelonian bones (including two specimens of the conjoined Y-shaped scapula and precoracoid) a lower jaw resembling those belonging to the reptilian genus *Mosasaurus,* sharks' teeth, *Nautilus, Ammonites Soutoni* and *Stangeri,* and several of the gasteropods and lamellibranchs mentioned from the similar bed to the north-east. It is probable that these outcrops of similar rocks belong to one and the same bed lying horizontally near the base of the Cretaceous deposits in this neighbourhood.

The overlying beds are best seen at the caves nearest the Umzamba mouth. The section is as follows :—

	Ft.	In.
13. Shelly limestone with *Trigonia*, &c.	0	10
12. Tough sandy clay, blue, weathering brown	1	4
11. Shelly limestone	0	6
10. Tough sandy clay	1	0
9. Shelly limestone	0	4
8. Tough sandy clay with large *Inoceramus*	3	6
7. Shelly limestone	0	10
6. Tough sandy clay	3	0
5. Black impure limestone with large numbers of shells throughout, especially at the base	0	6
4. Black shale with large *Ammonites*	1	0
3. Oyster beds	0	2
2. Thin bed of fine conglomerate with pebbles of black shale	0	3
1. Coarse conglomerate with shark's teeth, reptilian bones and large shells mostly broken	0	0
	13	3

Above No. 13 there are other beds partly or entirely concealed by the soil and sand, which were not examined *in situ* ; but from some fallen blocks they were found to be sandy limestones very much weathered, and the fossils in them were too fragile to be carried away ; those fossils we could recognise belonged to species which occurred in the lower beds.

The shelly limestones mentioned in the section are largely made of fragments of lamellibranch shells, such as *Trigonia*, *Arca* and *Pectunculus*, and are of the same nature as the coarse broken shell deposits seen below high water mark at many places on the modern South African beach, but the Cretaceous shell beds have been consolidated by the cementing together of the fragments by carbonate of lime. The shelly beds do not extend from one end of the line of cliffs to the other, any one that is followed gradually thins out and is perhaps replaced by another at a slightly higher or lower level.

The intervening sandy calcareous clay is always weathered to a brown or yellowish brown colour on the surface, and is there soft, so that it can be dug out with a knife. If, however, the rock is obtained in a fresh condition it is blue in colour, and fairly hard, often indeed very hard, and the fossils will not then break out from the matrix. There are several foraminifera in this rock, belonging to the genera *Vaginulina*, *Nodosaria*, *Uvigerina*, *Discorbina*, *Truncatulina*, *Textularia* ; conspicuous amongst the Invertebrate remains are *Hemiaster Forbesi* (an Indian form) and a species of *Cassidulus* both of which are very fragile, and were not found in the interbedded coarse rock.

Large examples of *Inoceramus expansus* are frequently seen in section looking like thin veins of calcite traversing the rock; an average sized specimen is three feet long; this fossil is very difficult to obtain in a perfect condition, and we were unsuccessful in the attempt. The other fossils obtained in these fine-grained beds are species of the following genera :—*Pugnellus, Fasciolaria, Scalaria, Solarium, Chemnitzia, Solariella, Avellana, Natica, Lagena, Turritella, Nerita, Actaeonella, Voluta, Fusus, Ostrea, Exogyra, Cardium, Protocardium, Pecten, Trigonia* (*T. elegans* and *T. Shepstonei*), *Cyprimeria, Crassatella, Cytherea, Arca, Pharella, Pectunculus, Lithodomus;* several cephalopods were found and amongst them *Ammonites Umbolazi*, and several other species, *Baculites, Anisoceras, Scaphites*, and *Helicoceras*. Reptilian and shark remains were also found. From a comparison of the contents of the different beds it seems certian that the greater number of species existed throughout the whole time occupied by the deposition of the rocks seen in the Umzamba section, but that in the coarser deposits, which were formed in shallower or more disturbed water than the finer, only the stronger shells were preserved; in the case of *Inoceramus*, which breaks up into characteristic little columns of calcite, the genus can be recognised in all the coarse beds, although one may look in vain for a whole specimen or even for a moderate sized piece. The very strong lamellibranchs such as *Pectunculus, Crassatella*, and *Arca* were observed in all the beds, but in the coarse grained deposits they are usually much abraded. We are therefore led to a different conclusion from that drawn by Mr. Griesbach, who considered there were five fairly distinct faunas represented in the caves-section. As the whole thickness of rock well exposed is perhaps not more than 20 feet, it is not surprising that so many forms are distributed through it; there are several species represented in our collection by only one or two examples, and these of course came from one bed only, among them are the delicate shelled cephalopods, *Scaphites* and *Helicoceras*, which were found in the upper thick sandy limestone, No. 8 in the table of the caves-section, but with our present knowledge it would be rash to conclude that even these species are confined to that one bed.

The repeated alternation of two varieties of sediment, one of which is a coarse shelly rock, perhaps a beach deposit, and the other such as might be formed in water deep enough to prevent the action of the waves being felt on the bottom, but still sufficiently near the land to receive a large amount of sand and mud, seems to point to their having been formed in a sea where the currents were liable to very considerable changes, so that an area of quiet deposition suddenly became one where none but heavy fragments could fall to the bottom and remain there. It seems out of the question to suppose that the differences in nature of the deposit were caused by alternate risings and sinkings of the sea-floor, or that such a slight decrease in depth of water brought about by the deposition of three feet or so of sandy mud could bring the sea-floor within the action of waves which did not make themselves felt before.

In part of the lowest beds exposed on the beach near the north-east end of the outcrops, the rock has been hardened by the deposition of chalcedonic silica, and this material has replaced the carbonate of lime of several of the fossils very beautifully, so that the fossils stand out on the weathered surfaces of the rock ; amongst those preserved as siliceous pseudomorphs we collected *Baculites, Teredo, Cardium denticulatum, Turritella Bonei,* and *Solarium pulchellum,* while fragments of many others were seen.

On the coast of Pondoland, about seventeen miles north-east of the mouth of St. John's River, there is a series of conglomerates and coarse green sandstones stretching from near the Embotyi River to the south-west end of the Waterfall Bluff. They are of very great interest because they contain pebbles and boulders of the dolerite which is intrusive in the Karroo Beds. Until these beds were found there was no evidence to fix the latest limit to the period of the dolerite intrusions.

The Embotyi Series is only exposed on the shore, and for a short distance inland. At the south-western end of the outcrops the junction with the neighbouring rock was not seen, but the nearest outcrops are of beds belonging to the Ecca or Karroo Series, in which obscure plant remains and some fragments of bone were found. These Ecca or Karroo beds dip at varying angles to the south-east, or east-south-east ; their angle of dip is sometimes as high as 35° ; they contain dykes of dolerite, and near the St. John's River sheets of dolerite were met with in the same beds. It is probable that the Embotyi rocks lie unconformably upon these beds, for the latter have furnished pebbles to the former, and a fault separates both series in this locality from the Table Mountain Sandstone.

The beds of the Embotyi Series lie nearly horizontally near the south-west end of the outcrops, and it is probable that they rest unconformably upon the underlying Ecca or Karroo Beds. Further to the north-east the beds have have a dip towards the north-east of about 20°, the dip turns northwards near a conspicuous green conical hill and varies from 0° to 15° and near Waterfall Bluff the coarse conglomerates dip 10° south.

The finer grained rocks of the Embotyi Series are met with about the middle of the line of outcrops, near the Umgwegwane River, and they are well-bedded, but towards each end the rocks are much coarser and are usually true conglomerates, and often show little sign of bedding. At the south-west end near the Embotyi the sandy soil and vegetation extend to the beach and the greater part of the conglomerate is hidden, but at the north-west end, for about half a mile round the shore from Waterfall Bluff, the conglomerate is magnificently exposed in some of the highest cliffs we saw on the Pondoland coast. The conglomerates here rest against a vertical wall of Table Mountain Sandstone, evidently a faulted junction, for slickensides can readily be found on the surface of the sandstone, and the line of fault here is continuous with the southern boundary of the Table Mountain Sandstone on which the Egossa Forest stands. Further west the fault separates the Ecca Beds (possibly a part of the Dwyka comes in too) from the Sandstone, and to the east the fault encarpment runs out to sea as a cliff rising 300 feet from the water, and over it there fall the small streams from the country immediately behind the cliff, from which the name "Waterfall Bluff" is derived. The conglomerate in the neighbourhood of the fault-face contains very large boulders of dolerite, some of them 12 feet in diameter, smaller boulders and a coarse sandy matrix fill up the interspaces between the large boulders. There are numerous fragments of dark mudstones and sandstones such as might well have been derived from the Karroo and Ecca Beds into which the dolerite was intruded. The form of the largest boulders is irregular, and the edges are only rounded off to a moderate extent; but the smaller fragments are much more rounded, and those small enough to be called pebbles do not show any traces of their former angular shape. The absence of any pebbles or boulders of the light coloured rock belonging to the Table Mountain Sandstone is very noticeable in the coarse conglomerate under Waterfall Bluff, where the two rocks are in contact. It is very probable that the Table Mountain Sandstone was not exposed in this district to nearly the same extent as it is now and perhaps not at all, during the formation of the conglomerate. Patches of brown translucent calcite were frequently noticed occupying small cavities, one to two inches across, in the coarser parts of the conglomerate, as if the rock had been rather loosely piled up, and the sandy matrix had been insufficient to fill up all the interstices between the rock fragments. A few hundred yards south-west of the Waterfall Bluff there is a conical grass-covered hill jutting out into the sea, and on the south side of it there are sections of the conglomerate, which is here less coarse than nearer the Bluff. The matrix is a green sandy rock, and contains fragments of all sizes, up to great blocks 15 feet long by four wide; these large-sized pieces are, however, few in number, and the proportion of boulders and pebbles to the amount of matrix is much less than in the conglomerate nearer Waterfall Bluff.

It is evident from the great size of the boulders in the coarse conglomerate at the north-east end and the increasing coarseness of the rock as we pass from the middle of the line of outcrops towards each end, that the source of the boulders lay north or north-west of the present position of the outcrops, and that it could not have been far distant; whether the rocks were deposited in sea or fresh water, the shoreline was near at hand.

The only signs of organic remains found in these rocks were in the finer grained parts of the outcrops below the level of high water near the middle of the outcrops; they were fragments of carbonized wood, and were of no use in determining the age of the rocks. Our visit to the locality was of necessity a short one, and a further search is likely to be rewarded by some evidence which will throw a certain light upon the relationship of these sandstones and conglomerates to other rocks in the country. From the similarity of the position of the Embotyi Series to that of the Cretaceous Beds to the north-east, it is probable that the two are closely connected, and if a statement in Garden and Baily's paper (loc. cit. p. 454) is confirmed, that the Cretaceous rock occur at the mouth of the Umtata River, it will support the conclusion arrived at, that the Embotyi rocks belong to the Cretaceous Series.

In general lithological character, these conglomerate and sandstones of the Embotyi Series remind one irresistibly of the Enon Conglomerate and Zwart Kop's Sandstones of the Uitenhage Series; the chief difference between them (in addition to the one as a rule being green and the other red) is the presence in the former series of so many boulders and pebbles of the Karroo dolerite, while this rock has not been found in the Enon. Supposing, however, that the dolerite had been intruded before the deposition of the Enon, the distance of the known outcrops of that rock from the nearest dolerite sheets of the Karroo would sufficiently explain the absence of fragments of dolerite from the Enon Conglomerate.

The conditions of deposition of the two conglomerates were probably similar, and it is very likely that the relationship of the Embotyi conglomerate to the marine Cretaceous Beds is similar to that of the Enon Conglomerate[1] to the marine beds of the Uitenhage Series.

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(1) See Annual Report, Geological Commission for 1900, p. 4.

APPENDIX III.

THE GEOLOGICAL SURVEY OF THE DIVISION OF KENTANI.

BY

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The Division of Kentani is part of Gcalekaland and comprises an area of some 450 square miles situated between the Gcua and Kei Rivers on the south-west, the Kogha River on the north-east, the main road from Butterworth to Idutywa on the north-west, and the sea coast on the south-east.

The country may be broadly described as a series of plateaux rising by three stages from the sea-level. The coastal district slopes up gradually to a height of about 1,000 feet, above which there is a terrace extending to the foot of an escarpment, above which again there is a plateau which forms the greater part of the division; the village of Kentani, the residence of the Magistrate, lies on the top of the escarpment. The height of the main plateau is about 2,500 feet above sea-level.

The Kentani Hill, or Quintana Tree Hill as it is called on the divisional map, is the only marked eminence in the district; it is a small hill that rises about 100 feet above the main plateau.

The surface of the Kentani plateau is somewhat undulating, the only large tract of practically flat ground lies between Gobogobo and N'Hlambe. The plateau character of the country is particularly evident when the river valleys are taken into consideration. The larger rivers, especially the Gcua and Kogha, which rise beyond the limits of the division, lie in deep steep-sided valleys, a feature which is even more strikingly seen in the case of the Kei River. The tributaries of these large rivers are quite insignificant in length, none being more than seven miles from source to mouth, but their valleys deepen very rapidly, and may have a fall of some 2,000 ft. from the plateau surface to their point of confluence with the larger rivers. The Tutugha stream is an example. It flows from the flat country south-west of Gobogobo in a rapidly deepening valley, unbroken by any waterfall, into the Gcua; the sides of the valley are very steep, in some places precipitous; the length of the stream is under seven miles in a straight line from source to mouth, and the windings of the bed are inconsiderable; the depth of the valley about midway between source and mouth is some 900 ft.

The tortuous course pursued by the Gcua and Kogha and also in a less marked degree by the Kei, make the topography of the country bordering them very complicated, and add very greatly to the difficulties of traversing the country from point to point. The general direction of the Kogha and Kei is a south-easterly one, the Gcua runs south in the Kentani Division, and the minor streams which flow into the sea have a general south-easterly direction.

Of the streams which lie entirely within the Kentani division the Kobonqaba is the largest. It rises in the Tekoe Location on the Kentani plateau and flows in a rapidly deepening valley to the sea, some 23 miles distant in a direct line; throughout its course the stream resembles the larger rivers in having a very tortuous course with tongues of high ground occupying the larger loops. The river in the last three miles of its course is tidal, and is there considerably wider than in the immediately preceding portion; it enters the sea between rocky points.

The streams yet to be mentioned which enter the sea separately, all rise below the Kentani escarpment, or below the corresponding feature on the north-east side of the Kobonqaba. Between the Kei and Kobonqaba are the Gxagha and Kologha, each with a sinuous course, steep valley and considerable tidal lagoon, separated from the ocean by sand-bars which in dry seasons stretch completely across the mouths. North-east of the Kobonqaba are the Wheeli, Nxagha, Umfane, Istamfoona, Umtilwana, Manubi and Kleena Rivers, all of which rise in the plateau above the face of the Manubi escarpment. The Manubi escarpment is a feature that has no exact counterpart in the western part of Kentani; it is an abrupt break between the coastal slope and the plateau below the Kentani escarpment. The Wheeli and Nxagha have a common lagoon, which, like the lagoons of the other rivers named, is held in by a sand-bar that occasionally shuts it off entirely from the ocean. These rivers, like those already described, have winding courses and very steep-sided valleys, a conjunction of characters which are rather incongruous; it is due to their original course on the plateau surface being perpetuated after the general rising of the land; the consideration of this point will be taken after the geological description of the country has been given.

Several smaller streams of from one to five miles in length are found along the coast; they all end in lagoons which are closed by sand bars, only broken through in times of very heavy rain. The level of the water in the lagoons is often considerably above that of the sea at low tide which indicates an unexpected compactness of the sand-bar.

A remarkable series of east and west tributary valleys between the Gcua and Kogha Rivers requires description at this stage. Taken together they form a well-marked depression, in some parts two depressions running parallel and about a mile apart, owing to the col separating any two valleys lying considerably lower than the surrounding plateau. The features thus produced have long been known under the name of the Transkei Gap, which is marked on the small scale maps of the Transkei, issued by the Surveyor-General. They owe their origin to the presence of long dykes of a sort of diorite, to be described later, along which denudation has been able to work more rapidly than elsewhere in the immediate neighbourhood, and has caused the river-valleys to follow the course of the dykes very closely. The valleys of the Gap extend westwards far beyond the limits of the Kentani Division, where they are first met with in the N'Debe River, and in part of the Tutugha, two tributaries of the Gcua, of which the N'Debe lies about a mile south of the Tutugha. The portion of the Gap in which the southern branch of the N'Debe runs is continued in the N'Gobe, a tributary of the Kobonqaba some five miles in length ; eastwards, the line is continued by a number of small valleys whose waters flow either into the Kobonqaba or Nxagha, as far as the divide near Lusizi, to the east of which the Kabakazi, a valley six miles in length, lies along the same dyke as far as its confluence with the Kogha ; from this point the direction of the last six miles of the Kogha is determined by the course of the dyke. A similar dyke occurs in the valley of the northern affluent of the N'Debe and can be followed across the low nek just north of the Gobogobo trading station, then along two branches of an affluent of the N'Gobe, and across a low divide separating the eastern of these from another shorter tributary of the Kobonqaba ; eastwards of the Koboqaba the gap is continued in the valley of its tributary, the N'Kukuwana, but beyond this the feature is not well seen for some miles, although the dyke is met with on the side of Cat's Pass ; a number of small valleys, mostly affluents of the Kabakazi, continue the gap as far as the Kogha, which it crosses about half a mile north of the Kabakazi mouth. The length of the Transkei Gap in the Kentani Division, from the Gcua to the mouth of the Kogha, is about thirty-two miles.

The country is throughout covered with grass, except along some of the river valleys and part of the coast, where the forest is still found. The only considerable tract of forest is that of Manubi, covering the slopes of an escarpment. The presence of trees seems to be a favourable condition for the formation of the very steep-headed and steep-sided valleys frequently met with in the Transkei. The head of one of these valleys is as steep as the sides some way below ; there is very little running water in most of these valleys, and except after rain the upper part of the stream bed is often dry. Where these valleys have been let alone by the natives, who like burning and cutting down the forest in order to raise heavy crops from the virgin soil, they are clothed with forest, which protects the underlying rock from denudation ; the stream wears away its bed almost as quickly as if no forest grew on the valley slopes, but the sides and head of the valley are protected by the vegetation, owing to its breaking the force of the rain by covering the soil with dead sticks and leaves. In the grass country the ground is covered with innumerable small round pellets, the castings of worms ; these pellets are fairly consistent, and are washed away like sand-grains during the first fall of rain. They break up before long, but they certainly facilitate the removal of the soil, which is rarely found to be a foot in thickness on the grass-covered land.

The rocks of the Kentani Division belong to the Karroo Series and include much dolerite in the form of sheets. As will be seen later, the sedimentary rocks are probably of about the same age as those of the Nieuweveld ; indeed the geological structure of the two regions is very similar. In spite of this similarity the appearance of the Kentani country is very different from that of the Nieuweveld ; the vegetation is of quite another kind ; instead of the small thick-leaved bushes, with nothing growing between during dry seasons, we have in Kentani a covering of grass, and a luxuriant growth of trees and large bushes is found where the axe and fire have not destroyed them. The sharply scarped table-shaped hills and spitz-kops of the Nieuweveld are not found in this district ; the outlines are everywhere more rounded, and the geological structure is not so evident as in the Nieuweveld. This difference is largely due to the moister climate of Kentani, but it also depends upon the difference between the recent geological histories of the two districts ; for as will be shewn later the Kentani country must have been much nearer the sea level within recent times than it now is.

The plentiful vegetation of the Transkei is frequently an obstacle to the investigation of the geological features, as the rocks are much weathered superficially and are completely hidden over large areas ; this is particularly the case with the sedimentary rocks.

THE SEDIMENTARY ROCKS.

The Sedimentary rocks of Kentani Division belong, with exception of the recent surface-deposits, to the Karroo Series. They fall into two groups which are, however, very difficult to distinguish, the higher group forming the bulk of the sedimentary rocks of the Division and which we may therefore call the Kentani Beds, and a lower group, found only on low levels near the sea-coast and on the north-east, which we have called the Idutywa Beds, because of their occurrence at that town.

The Kentani Beds consist of shales and mudstones with only occasional sandstone beds. The colour is black in fresh sections, the shales weathering light green or grey-blue, and the sandstones to light blue and finally to yellow. The large amount of dolerite that has been intruded into these beds has altered them in places over a large area so that they are now mottled and spotted, while elsewhere, nodules of green material, consisting largely of epidote, have been formed in the substance of the rock. There are very few sections available for studying these beds as the sides of the steep river valleys are either covered with rubble and soil, and grass-grown, or are inaccessible precipices. West of Tutugha Mission Station there is a bend of the Gcua River, on the Butterworth side of which there is a long, straight, almost vertical section, with a sheet of dolerite on top, looking like a palisade on account of its rough columnar structure ; this is locally known as the Bower, and on the Kentani side there is a path leading down to the river showing a long exposure of sedimentary rocks. These consist entirely of shales weathered a light blue and breaking up into flat bits and not into starch-like fragments as in the dryer Karroo. Under the dolerite sheet on the opposite side the sedimentary rocks are blue-black in colour, well-bedded but with no signs of division into sandstones and shales. East of the Tutugha along the main road there is a small exposure of sandstone weathered into yellowish slabs and at other places in the neighbourhood on this level the same sandstone crops out. Fossil wood was found near Butterworth along the main road, especially near Toleni, and though it occurs in beds of the same age, it was not found by us in the Kentani Division. Above the N'Hlambe sheet at Gcua location there is a thickness of black hornstone-like rock which weathers brownish white, a shale altered by the underlying dolerite. This hornstone was seen also on Zitsane beacon but not elsewhere in the district, although it is probably to be found in many other places. The west and north of the Division contains these Kentani Beds, but in the north-east we find a greater variety of rocks which leads us to suspect the presence of a different set of beds, and to the south along the coast undoubted Idutywa Beds are met with. This is due to a general north-westerly dip of the rocks, the dip being very slight and rarely noticeable in small outcrops ; so that along the south-east, east and north-east, the Idutywa Beds underlying the Kentani Beds come to the surface.

On the north-east along the road from Cat's Pass to Willowvale we got the following section. On top of the road there are the ordinary light-blue weathered shales ; as we descend we come on thin-bedded yellow sandstones and shales, and towards the bottom, purple shales, massive blue sandstones, and mottled and spotted rocks. Where the mottling occurs, the rock, usually sandstone, is very much indurated, and there has probably been some alteration by heat from the dolerite intrusions. The same kind of alteration is often seen round Graaff-Reinet. The Kogha River here makes several loops, at places cutting into the hill-sides and forming high precipices, at others enclosing low circular stretches of ground, which the cutting of a small nek, separating the loops, would convert into an island. The erosion of this part is especially rapid, and the steep hill-sides do not afford typical exposures of the rocks, such as we get round Idutywa, so that it is unsafe to correlate these beds definitely with those of Idutywa, but at any rate we know they occur towards the bottom of the Kentani Beds.

In the south-east of the district we get many excellent exposures along the sea shore, where the beds are characterised by their diversity of colouring and hardness. The most typical rock is a light yellow sandstone with hardened calcareous nodules, occurring in banks from two to three feet thick, laminated and false-bedded. The nodules weather out as rounded balls, or elongated lumps, which stand up from the surf-worn surface of the rock; these are often broken across the middle and have their centres worn out, leaving cup-shaped forms. With this rock there are red, purple and blue shales, hard white or gray micaceous sandstones, and indurated black shales; the surface of the latter on the shore is covered with little square holes, which have been worn by the waves and give the rock a scoriaceous appearance. All these varieties alternate in thin beds sometimes with a dip of as much as 10° to the north-west, at other places with irregular dips induced by the intrusion of the dolerite. In the black shales about two miles east of the Kologha mouth we found some reptilian bones. The lower part of a skull is that of an *Oudenodon* and the general size and nature of the bones would correspond with animals of this type; the rock was very hard and had many epidote nodules in it; the rock also readily breaks up into splinters, so that the bones came out in a very fragmentary condition. At Mazeppa Bay the same rocks occur but the dolerite has caused great disturbances, and blocks of sedimentary rocks dip east, contrary to the general dip of the rocks in the neighbourhood. About half a mile from the huts at Mazeppa Bay there is another small bay on the west side of which we got the following succession from below upwards :—

1. Massive yellow sandstone in beds from 9 in. to 2 ft. in thickness.
2. Blue-black hard shale, about 1 ft. thick.
3. Massive grey sandstone with white sandy patches, much alteration material.
4. Light yellow micaceous sandstone, very hard and much fractured.
5. Black shale worn into little holes on the surface.

6. Light yellow fine-grained sandstone, much fractured, with the joints filled in with sandy material which is harder than the rest.
7. Massive black shale hardened by heat.
8. Thin bed of light grey sandstone.
9. Dark grey argillaceous sandstone with patches of light grey soft sandy material.

A dolerite sheet cuts irregularly across all of the above beds.

On the Takazi River, a tributary of the Kobonqaba, there is a deep hollow into which the river falls ; here there is a section of the sandstones and mudstones on a higher level than those on the coast. At the edge of the waterfall there is a krantz about 40 ft. high composed of yellowish sandstone in beds some 12 feet in thickness and jointed into blocks of about thirty-six square feet in section. The lower 120 feet of this fall is made of hard blue mudstones with many epidote nodules formed probably by the influence of the dolerite dyke that runs across the valley just below the falls. The sandstone weathers to a tough loose rock of the consistency of a freestone, and is very noticeable, as nowhere else in the district does one find a suitable stone for building purposes ; on the other hand, directly we get beyond Idutywa on the main road rocks of a similar nature are abundant. Although correlation by lithological characters is unconvincing and unsatisfactory, it is here all we have to go upon, and at any rate makes it probable that the Takazi water-fall rocks, and those on the sea shore below, belong to the Idutywa Beds. Two hundred yards below the falls there is a section showing an unconformity. The upper beds are false-bedded sandstones and shales, those below the unconformity are of a similar nature but more thinly bedded. Many small calcareous concretions are contained in the rocks both above and below the dividing line. The plane of the unconformity has a southerly dip and cuts obliquely across the lower beds. There is no evidence of any considerable change of physical conditions during the deposition of the rocks separated by the unconformity ; the occurrence is an example of what is sometimes called "Contemporaneous erosion and deposit," a phenomenon that differs in degree and not in kind from ordinary false-bedding.

Summing up our knowledge of the sedimentary rocks of the Kentani Division we find two series ; the Kentani Beds, composed of shales and mudstones with occasional sandstones, and the Idutywa Beds, composed of light coloured sandstones of looser grain than those in the Kentani Beds and blue-black, red, blue and purple shales. Practically the whole of the sedimentary rocks of the division belong to the Kentani Beds, but in the lower levels on the north-east and south-east sides, the lower beds, the Idutywa Beds, are brought in by the slight north-west dip of the strata

THE IGNEOUS INSTRUSIONS.

A very considerable part of the rock immediately underlying the soil and appearing at intervals above it is dolerite. Perhaps one third of the whole area of Kentani is thus constituted. The dolerite occurs as sheets and dykes, though by far the greater proportion of the rock is in the form of sheets.

In describing the sheets it will be convenient to commence with the lowest ones, and take the others in the order of upward succession. We have seen that the lowest sedimentary strata are met with along the coast and on the north-east side of the Division and that we reach higher and higher beds as we go inland and north-westwards. It will be evident from the description of some of the sheets that any one sheet is not closely confined to one particular horizon, but that it may traverse the beds at a low angle. It would indeed be difficult, perhaps impossible, to prove conclusively that an extensive sheet lies always between the same two beds of rock, for in the absence of fossils and clearly recognizable and constant lithological differences between successive strata, there are no means by which distant outcrops can be correlated exactly; and in a country so well covered with vegetation as the Kentani Division, a particular bed cannot be followed continuously for any considerable distance.

Between the Kei and Kologha Rivers there are four dykes of dolerite exposed on the shore, and one irregularly shaped mass which is probably the upper surface of a sheet. The upper surface of a sheet is often very uneven, owing to the dolerite rising obliquely across the beds of sedimentary rock, and again returning to a lower level within perhaps quite a short distance. Three of the dykes run nearly east and west, a fourth on the west of the Gxagha mouth strikes south-east; one of them, that nearest the Kologha, is 100 ft. in width, which is larger than most of the dykes seen along the shore.

A short way inland from the Kei mouth there is a low hill capped by dolerite in a form of a sheet, lying at a considerably lower level than the escarpment of the great Kologha sheet, which is first met with about four miles further inland; probably the two sheets were never directly connected.

Along the shore north-east of the Kologha mouth two N.N.E. dykes of small size appear. They are close to the south-west end of a sheet which forms the shore, and the country just behind it for some nine miles to the north-east. This mass of dolerite may be called the Kobonqaba sheet for convenience, as the river of that name lies in it for the last four miles of its course. At the south-west end on the shore the sheet appears from below purple and grey sandstones, which are much hardened within some five feet of its surface; the sandstone and the underlying sheet can be followed along the hills on the south-west or right bank of the Kobonqaba River to within a few hundred yards of the mouth of the Takazi River, a tributary of the Kobanqaba from the north ; here the Kobonqaba sheet passes below the surface, and is not met with further north. The upper boundary is continued eastwards in a sinuous line, following the contours of the hills, of which the upper slopes are made of the hard gritty sandstones, and the lower of the dolerite. From the point where the Wheeli River crosses the junction, the boundary between the two rocks runs north-east for about four miles, when it turns abruptly south, and reaches the coast again half a mile south-west of the Umfane River. Following the sheet along the shore north-east of the Nxagha River, its continuity is broken by the intervention of an overlying mass of light-coloured sandstone and dark mudstones, in which green patches of epidote occur. These sedimentary rocks form the shore for about a mile, and end abruptly against vertical face of dolerite, which belongs to the Kobonqaba sheet, as it can be traced westward, inland, till it joins up with that sheet of which we have traced the boundary north-eastwards from the Wheeli and Nxagha Rivers. The vertical junction on the shore is probably a fault, with downthrow to the south ; the fault runs nearly due west from the shore, and appears to decrease in throw as it does not affect the continuity of the outcrop along the northwestern boundary.

The north-eastern boundary of the sheet is difficult to follow on account of the thick sandy soil which hides the rock. Only a few isolated outcrops were seen, but they seem to justify the following account of the sheet in this part of its course. The sheet breaks through the sandstone beds lying above it along the Kobonqaba ; along the south-west side of the Umfane it lies above the same sedimentary rocks, although these are continuous with the strata overlying the sheet round the north-east end near the Wheeli and Kobonqaba.

It is difficult to arrive at an estimate of the maximum thickness of the Kobonqaba sheet. On the Wheeli River there are vertical cliffs about 100 ft. in height cut in the dolerite, but the ground to the west of the river in this neighbourhood rises some 300 ft. above the level of the river and appears to consist entirely of dolerite, so the thickness of the sheet at this point is at least 300 feet.

An isolated area of dolerite capping the hills between the Umfane and Istamfoona Rivers is probably an outlying portion of the Kobonqaba sheet, separated from it by the valley of the Umfane.

The Kobonqaba sheet is traversed by dykes of more acid rock, much lighter in colour than the dolerite, these dykes are well seen on the shore north-east of the mouth of the Kobonqaba River, but similar rocks crop out on the surface two miles north-east of the mouth, and on the left bank of the Nxagha River, about a mile above its mouth. Although the manner of occurence of the acid rock in the two latter places is not obvious, for the outcrops are scattered and disconnected, it is probable that their relation to the dolerite is like that of the dykes on the beach.

Leaving the Kobonqaba and proceeding north-east along the shore, a dolerite dyke 50 feet wide, running nearly east and west is seen near the Umfane mouth, and a second dyke 300 feet in width, nearly parallel with the last, traverses the sedimentary rocks at the mouth of the Istamfoona River, a short way from the Umfane. Between the mouths of the Istamfoona and the Manubi Rivers three dykes are to be seen, one of which is 100 feet in width ; four more dykes occur between the Manubi mouth and a large mass of dolerite on the shore a mile east of that river. This outcrop is about a quarter of a mile wide, and passes under the sedimentary rocks on each side ; it is probably the top of a sheet, of which several other similarly exposed portions are seen between it and the Kogha River. In a small inlet south-west of Mazeppa Bay there is a good section showing the upper surface of this sheet cutting obliquely across the sedimentary rocks for about four feet, and then abutting against the under surface of a thick bed of sandstone dipping east, along which it passes beneath the surface of the sand. It re-appears a little way off in the same manner cutting obliquely across some of the beds and then passing under the lower surface of a bed of sandstone. Where the dolerite cuts across the beds, the sandstone is traversed by joints parallel to the surface of the dolerite. The sedimentary rocks are much hardened, but except for the aggregations of epidote in the argillaceous layers, no contact minerals are visible to the naked eye.

The shores of Mazeppa Bay and the island off the coast are formed of dolerite, which also extends across the mouth of the Nebbelelli River. It forms a cliff about 100 feet high overlooking the sea to the east. The same sheet is found at the top of the estuary of the Kleena River, forming a krantz rising about 30 feet above sea-level. From here it can be traced as a thin sheet whose outcrop surrounds the lower basin of the Kleena River, then it passes westwards and forms the tops of low hills overlooking the estuary of the Manubi River.

The upper half of the Kologha valley lies in an extensive sheet of dolerite of which only a part is exposed in the Kentani Division ; the western end is in the Komgha Division. It may conveniently be called the Kologha Sheet. The main part of the sheet extends eastwards from the Kei River below the junction of the Gcua. The cliffs and slopes of the left bank of the Kei for a distance of about four miles rise some 1,200 feet above the river and two-thirds of the vertical height are composed of the dolerite of this sheet ; the tops of the hills on Inver Gcua, Fairy Dale, Wesley and Mimosa Hill, farms marked off on the divisional map along the left bank of the Kei, are thinly capped by a hard sandstone lying on the sheet. The junction of the two rocks makes a very sinuous line on the surface, bending far into the plateau round the deep, steep-sided ravines which have been cut back into it.

On the lapsed* farm named Inver Gcua the Kologha sheet dips northwards across the sedimentary rocks, and a good section of the junction occurs here in the bed of the Kei River. Eastwards the sheet gives off two thin sheets which were followed for about two miles round the north side of the Inver Gcua ridge, whence they are continued as one sheet, some 50 feet in thickness, through the farms Wesley, Raven Hill, and Over Reach, and occupy a considerable area in the south-west part of the Quintana Reserve. A corresponding off-shoot of the Kologha Sheet leaves the main mass on the eastern side of the Inver Gcua and Wesley hills on the farm River Stone, and runs up a side river towards the Kentani escarpment; at the head of this river the dolerite forms the bed of the river and is at least 50 feet thick, but here it is connected with a thin sheet which winds round the south side of the Kentani escarpment and again joins the Kologha sheet about two miles south-east of Kentani. From River Stone the northern limit of the outcrop of the main part of the sheet takes an irregular course to the east, bends round the sandstone-capped hill separating the Nyntugha and Kologha valleys and forms the bed and greater part of the valley-slopes of the Nyntugha River, a tributary of the Kobonqaba. For some three miles south of the Nyntugha the bed of the Kobonqaba lies in the Kologha sheet, but further north the sheet is considerably thinner, and forms a band of decreasing width round the hills and valleys as far as the bend below the Columba Mission Station. Above the bend the sheet forms the bed of the river, partly because a fault running north-west through the Columba Mission Station, drops the rock on the north-east side, but chiefly owing to the sedimentary rocks and the enclosed sheet dipping towards the north-west at a low angle. After forming the bed of the river to within a short distance of the N'Gobe River, the sheet disappears from view in the river valley, and is not again seen on the west of the Kobonqaba. To the east of the river the sheet rises in level, probably by breaking diagonally across the sedimentary rocks, and occupies a considerable area to the south-west, north, and north-east of the Nxaxo trading station. In this neighbourhood the Kologha Sheet is traversed by one of the diorite dykes already mentioned as being the cause of the Transkei Gap valleys. From Nxaxo, where the sheet forms the surface of the plateau, the eastern limit trends southwards, taking many curves round the head-waters of streams which flow into the Nxagha River. The sheet is considerably thinner east of N'Quise than on the Kobonqaba near the Nyntugha, for it forms but a small part of the valley-slopes to the east of the sandstone-capped plateau on which N'Quise stands; and at the south-east end of the tongue-like projection of the sheet, which stretches about four miles from N'Quise, the sheet disappears altogether in a ridge separating the Wheeli River from the N'Guisi. South of N'Quise the road to the Kobonqaba mouth passes over the long sloping face of an escarpment which here separates the high plateau on which N'Quise and Nxaxo stand, from a lower one. The escarpment is cut out of the Kologha sheet the bottom of which has determined the foot of the escarpment. From the point where the road leaves the escarpment the southern limit of the sheet trends south-west nearly as far as the Kobonqaba River, where it turns south, and the dolerite forms the lower part of the valley east ot the river. The river crosses the lower boundary of the sheet some four miles north-north-east of Kemlo's trading station, and from this point the outcrop of the sheet turns south-west as far as the Kologha River, near Kemlo's shop. From Kemlo's the outcrop runs west forming the top of the river-cliffs overlooking the Kei; at the same time the level of the sheet descends, and it eventually forms the bed of that river at Fairy Dale, about ten miles west-north-west of Kemlo's. The area covered by the Kologha sheet in the Kentani Division is about eighteen miles long from west to east, and twelve from north to south. It is improbable that the sheet ever extended far to the east of the outcrops still remaining, as we have seen that it thins out at one place between the Wheeli and N'Gusi Rivers, but it may have had a much greater extension southwards for the denuded edge of the sheet is seen in that direction; to the west the sheet occupies some part of the Komgha Division, but has not yet been mapped there; on the north we have seen that the sheet gives rise to thin off-shoots, the extent of which was probably never much greater than the area now indicated by their outcrops.

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* A considerable number of farms were at one time surveyed and given to people in consideration for military service against the Kaffirs. Most of these were never occupied, and the ground has reverted to Government.

There are some small isolated outcrops of sheet-like masses of dolerite which may be with some certainty be referred to the Kologha Sheet; one is a triangular area on a hill-top between the upper part of the Wheeli River and the Takazi; another forms a V-shaped outcrop round a spur projecting between the two largest affluents of the Kombolo River on the farm Wesley. The lower part of the steep valley of the Umnyama River which flows into the Gcua about three miles above its junction with the Kei, is cut out of a thick mass of dolerite which has a steep southerly dip. Whether this dipping sheet, which cuts across the sedimentary rocks, is in direct connection with the Kologha Sheet may perhaps be determined in the Komgha District, at any rate the outcrops of the two dolerite masses suggest a synclinal bending of the sheet.

The thickness of the Kologha sheet varies greatly. On the Kei, aneroid measurements gave a thickness of 900 feet for the sheet near Mimosa Dale, where both the bottom and top of the dolerite are found in the same section. On the Kobonqaba River below Nyntugha about 500 feet of dolerite is exposed on the precipitous west side of the valley, but the top of the sheet is not seen there; further to the north and east as we have seen, the sheet becomes very thin, and disappears. The amount of dolerite in the Kologha sheet is very great, and it might be expected that a dyke would be found occupying the channel through which rose the molten material that spread out laterally and solidified in the form of the sheet. So far as our investigation has gone, no such dyke or feed pipe has been seen; it may be that the fissure or pipe is hidden below the area occupied by the sheet and the following two features may indicate the position of the hidden dyke. When two thick sheets of dolerite dip towards each other, either cutting diagonally across the sedimentary rocks, or following a synclinal fold in them, it is but natural to suppose, as Dutton pointed out, in the absence of any observed feeders, that the inclined sheets or dykes are the upper parts of the fissure or system of fissures through which the molten material came. In the case of the Kologha sheet two such inclined masses of dolerite can be seen near the junction of the Kei and Gcua rivers, although the northern one, described above from the Umnyama valley, is apparently of much less importance than the southern which rises from below the sandstone at Inver Gcua, and, as the main part of the Kologha sheet, caps the hills further to the south-east. The second feature is the line of greatest thickness in the sheet, if it can be discovered. In the case of the Kologha sheet the greatest observed thickness is just south of Inver Gcua, but it is impossible to find out the comparative thickness of the sheet at different places in the wide area between the Kei and the Kobonqaba, as the once overlying sedimentary rocks have been denuded away, together with the top part of the sheet,

It is not unlikely that the Kobonqaba sheet, which has been already described, was formerly in connection with the Kologha sheet, but they are now separated by an area in which no outcrops of dolerite appear; the Kobonqaba sheet also lies at a somewhat lower horizon than the other.

In the eastern part of the Division there is a sheet which occupies a similar position to that of the Kologha sheet. It occurs in the Manubi Forest, and on the hillside along the Kogha Valley. The outline of the dolerite exposed on the surface is very sinuous, as the sheet crops out on the face of an escarpment, which is cut back by many streams, the head waters of the Istamfoona, Umtilwana, Manubi, Kleena and Nebbelelli Rivers. The sheet has been traced six miles westwards from the Kogha River, to a few miles beyond the Gqunqi station, and it disappears on the north-east side of the hills between the upper part of the Istamfoona and the Umfane Rivers. At Gqunqi an outlier of sandstone remains on the sheet separated from the main area of the sandstone overlying the sheet by about a mile. The Manubi sheet is at least 500 feet thick near the junction of the Kabakazi stream with the Kogha River, and the streams north of Gqunqi have cut ravines quite 300 feet deep in the sheet without exposing the bottom. A short way up the Kabakazi, however, the whole hillside is made of horizontal sandstones and shales except for a thin sheet of dolerite near the top, which may be an offshoot of the Manubi sheet, although no direct connection was traced between them; to the west of the Istamfoona River, the Manubi sheet disappears under the high ground south of Lusizi; one small outcrop on the level of the plateau may be an off-shoot corresponding with those overlooking the Kabakazi. The Manubi sheet probably extends some distance into the Willowvale district, north of the Kogha. Along the Kogha and the lower end of the Kabakazi valley the Manubi sheet is bounded on the north by the coarse dioritic rock of the dyke which has determined the direction taken by these streams.

On the north of the Kabakazi there is a thin sheet which crops out along the top of the cliff forming the left side of the valley. It was traced by us five miles to the west, as far as the point just north of the Lusizi trading station. No connection was found between this and the Manubi sheet, or any other, but it lies in a position corresponding to that of the top of the Manubi sheet.

Just at the edge of the plateau in the neighbourhood of the village of Kentani there is a sheet which was traced round the head waters of the Kologha, the Nyntugha stream, and several smaller tributaries cf the Kobonqaba River, for a distance of about 8 miles along the outcrop. The sheet is not more than 100 feet thick at the most. The outcrop was not found to be continuous with that of any other sheet or dyke, but the rock is probably in direct connection with that of the Kentani Hill sheet, which is first seen about a mile to the north of the last outcrop of the Kentani sheet. The Kentani Hill sheet underlies the clays and quartzite forming the cap of the hill, and extends about a mile to the north and sends out a thin sheet southwards, which crops out near the edge of the plateau flanking the Kobonqaba, and as mentioned above, is probably continuous with the Kentani sheet along this edge. The thickness of the Kentani Hill sheet is not greater than 100 feet.

About two miles north-west of Kentani Hill a thin sheet is met with near the heads of the streams, which run south-eastwards into the Gcua River. It was traced for about a mile and a half along the grass-covered slopes but no connection with any other sheet was found.

Between Cat's Pass and Nqundwyu there is a very irregular sheet forming for the most part the tops of the hills overlooking the Kogha River, and the outcrop winds in and out along the sides of the steep ravines that the small tributaries of the Kogha have cut into the plateau. Near Cat's Pass the sheet actually forms the tops of the hills, but round Nqundwyu sedimentary rocks cover the dolerite. The average thickness of the sheet may be taken to be 100 ft. On the west of Nqundwyu the level of the sheet is lowered by the dip of the beds which here have a pronounced north-westerly dip, and the sheet also increases very greatly in thickness. About a mile and a half below the junction of the Tekoe and Umzintsane Rivers the greatest thickness is observed, the dolerite occurring as a coarse-grained rock in the bed of the rivers and extending some way up the sides of the river cliffs. From here northwards the sheet rapidly decreases in thickness and on the east side of the Umzintsane River, at its junction with the Tekoe, the sheet abuts abruptly against the edges of the sedimentary beds forming a vertical face ; there is no evidence of disturbance in the rocks. On the opposite side of the river the sheet is found near the top of the river cliff, some 50 feet in thickness, the rock being very variable in texture, sometimes coarse-grained, at other places becoming exceedingly fine-grained. Following this sheet up the Tekoe River it soon dies out altogether, but a small patch is found further up quite separated from the main sheet but evidently connected with it either underground, or by means of a bridge that has now disappeared. In the sheet we have the dolerite varying in thickness within a distance of two miles from 100 feet to nothing. The great mass of the dolerite in the bed of the conjoined Tekoe and Umzintsane Rivers is strongly suggestive of the spot having been the place where the igneous rock came up from the depths. In the hills of which this sheet forms the top there is usually a thin sheet cropping out at the foot, very irregular in thickness and discontinuous. The thickness of sedimentary strata separating this sheet from the upper one is from 500 to 800 feet, and if we consider the great mass of dolerite on the Umzintsane as the supply dyke, it is on that hypothesis possible that the lower thin sheet was given off from the same supply dyke as the higher.

The surface of the northern part of the Kentani Division, from the Gobogobo trading station to the main-road between Butterworth and Ibeka, is mostly formed by a sheet of dolerite, which we have called the N'Hlambe sheet, from the former

Residency of that name, now a farm, which is situated on it. The western side of the sheet so far as the Kentani Division is concerned is the denuded edge overlooking the valley of the Gcua River, which has cut through the sheet down into the underlying sedimenary rocks. The sheet undoubtedly extends westwards into the Butterworth Divison, and also northwards into Idutywa and eastwards into Willowvale. The southern boundary is defined by a denuded edge, beyond which appear the underlying sedimentary rocks. In the neighbourhood of Gobogobo the sheet is pierced by the northern of the two vertical dykes of the Transkei Gap, which is bounded by the dolerite on both sides for some three miles west of the trading station; further west an outlier of the sheet is cut by both the northern and southern dykes. Three other outliers were mapped to the south of the dykes, forming caps to parts of the plateau, which have been isolated by the cutting back of streams flowing into the Gcua. The Tutugha River has cut through the N'Hlambe sheet along some seven miles of its course. North and north-east of the Tutugha the sheet forms a great part of the surface. The Gcua River runs in a steep-sided valley some 800 feet below the surface of the plateau, the valley slopes are precipitous in places, and the lower surface of the N'Hlambe sheet is well seen. The thickness of the dolerite is about 500 feet, but the top of the sheet is removed west of the Tutugha Mission Station. Some five miles further up the river the sheet is thinner, for south-west of the old N'Hlambe Residency a thick cap of sandstone forms about two square miles of the surface of the plateau round Blyth's beacon, while the bottom of the sheet is considerably above the river. About three miles from Ibeka on the road to Manubi the road crosses another area of sandstone lying above the dolerite, and further on three more outliers of sandstone were found between the Manubi road and the Kogha River, on one of which Hughes' beacon stands. The bed of the Kogha River for the first six or seven miles of its course in the Kentani Division lies in the dolerite. The sheet dips at a very low angle to the north-west.

The dolerite sheets of Kentani appear to vary in thickness very rapidly compared with the sheets of the Nieuweveld and Calvinia. In the case of the Kologha sheet the line of greatest observable thickness lies between Mimosa Hill and the Kobonqaba near N'Cerana but on Inver Gcua a very thin sheet is given off from the top part of the main mass and the same phenomena is seen near the Columba Mission Station. The Manubi sheet also becomes quite thin near the trading station of that name. while it is 500 feet thick on the Kogha River a few miles away.

The peculiar dykes which have given rise to the chains of valleys of the Transkei Gap, are intrusive in the Karroo Series and the dolerite sheets. Near Gobogobo trading station the dyke cuts through the southern part of the great N'Hlambe sheet, and on the narrow ridge between the N'Debe and Tutugha Rivers the same sheet is cut by the dyke, and small veins of the dyke rock were found penetrating the dolerite of the sheets at a distance of a few feet from the main body of the dyke. This is clear proof that the dykes are of later age than the dolerite they penetrate. Although the dykes have penetrated the N'Hlambe sheet, the northern dyke north of Nxaxo does not cut through a dolerite sheet west of Cat's Pass, but it is probable that the rock is just beneath the sheet, for it crops out on the surface immediately to the east of the dolerite sheet on Cat's Pass, and on the same line a short way to the west near the N'Kukuwana River. Both the northern and southern dykes traverse thin dolerite sheets near Lusizi and between that place and the Kogha River. Along the Kogha the southern dyke has broken through the Manubi sheet, which is at least 500 feet thick at one point, and it is probable that the northern dyke penetrates the continuation of the same sheet in the Willowvale Division.

Near Gqunqi, south of the road between Lusizi and Manubi, there is an intrusive mass of acid rock, which may be called a microgranite; it is in the form of a short dyke, about a mile long and several hundred yards wide. It pierces the sedimentary rocks and the Manubi sheet, and is extended in a north and south direction. Judging from the fact of its occurring at right angles to the dioritic dykes, and under similar circumstances, it may be in some way related to the diorite, perhaps the last stage in the irruption of the dyke rocks of which the more basic dolerite was the commencement.

The sheets of dolerite generally have had much more effect on the sedimentary rocks near them than the dolerite dykes, probably on account of their greater bulk, for the dykes which we found in favourable positions for examination of the sedimentary rocks surrounding them were of no great size.

On the ground along the Gcua River west of N'Hlambe, marked "Gcua Location" on the divisional map, the beds overlying the N'Hlambe sheet are exposed on the hill slope; immediately above the dolerite is a band some ten feet thick of a black rock like hornstone, but which breaks with a conchoidal fracture, and weathers with a white crust. This variety of rock is very commonly found both above and below the dolerite sheets where they are in contact with argillaceous rocks, such as mudstones and shales. On Zitsane beacon there is also a similar hornstone although no dolerite is near from which we would infer that the N'Hlambe sheet once extended over that spot. Outside the zone of hornstone, the most prominent feature in the argillaceous rocks affected by the dolerite is the aggregation of epidote in roughly spherical or irregularly shaped patches up to about two inches in diameter. These epidote nodules are found also in rocks that are better called argillaceous sandstones than sandy mudstones, but they do not appear to have been formed in sandstones with a small amount of clayey material. These sandstones are much hardened, and have minute flakes of brown mica developed in them near the igneous rock, but to the unaided eye there is no apparent change in the sandstone other than the hardening. In a hard sandstone in contact with the gap dyke in the N'Debe River, a microscopic examination shows that the rock is made of quartz grains, and about an equal quantity of irregularly bounded patches of a cloudy biaxial mineral, with small bitsof epidote.

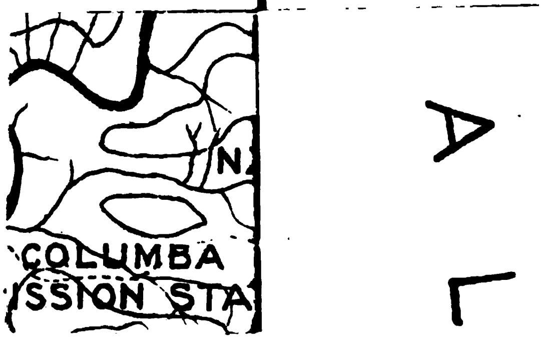
Kentani Hill (Quintana Tree beacon on the divisional map) is the only conspicuous elevation above the general surface of the plateau which stretches northward from the Kentani escarpment. It is made of a hard, sometimes vitreous quartzite, like those rocks called fresh-water quartzite, limno-quartzite or burr-stone; it lies upon variously coloured clays, which rest upon the denuded surface of a dolerite sheet. The quartzite is split up into many blocks by vertical joints; the surface is very rough, as the stone becomes pitted under the influence of the weather. The quartzite is composed of grains of quartz set in a siliceous matrix, which is usually more or less coloured with iron oxides, and is often slightly argillaceous. When the rock is struck, it breaks across the grains rather than round them as a sandstone does. Parts of the rocks are rather cavernous; small irregular holes often lined with minute quartz crystals penetrate the rock. The quartzite is only a few feet thick, and rests upon some 30 or 40 feet of clay in which small bits and crystals of quartz are embedded. In all respects the quartzite resembles many of the "surface quartzites" described in previous annual reports from the districts between George and Saldanha Bay, and a similar rock which occupies a wide area near Grahamstown. A hand-specimen of a similar rock from a farm about 9 miles south of Komgha village was given to the Commission by Mrs. Reany of that village. It is of particular interest because it contains the silicified seeds of *Chara*, and the shells of a gasteropod which looks like *Limnaea*. This is the first specimen of the surface-quartzite containing clearly recognizable fossils which has come to our notice.

There can be little doubt that the Kentani Hill rock is the last remnant of a river or fresh-water deposit which was once spread widely over the Kentani Division, possibly over every part of it. Its deposition probably took place during or just after the formation of the plateau of which it now forms the most elevated portion, but a discussion of the conditions under which it was formed must be postponed until we have a better knowledge of the Komgha outcrops.

The accumulations of sand along the coast do not form important features in the geology of the Kentani Division, although the sand is sufficient in quantity to obstruct the rivers at their mouths. Along the shore there is always more or less sand composed of grains of quartz and other minerals brought down by the rivers and worn off the rocks exposed to the waves along the shore, and of carbonate of lime from the sea shells broken up by the waves. In places the sand, or a layer on the surface contains a large amount of magnetite, which gives it a black colour. The magnetite is derived from the olivine-dolerites, which form a considerable portion of the fore-shore. On account of its higher specific gravity the magnetite is moved less easily by water running over the sand than the paler coloured minerals, and in consequence a wave during its retreat from a sandy shore washes away a great quantity of the grains of the light coloured minerals and leaves the surface of the sand with a much higher proportion of black magnetite than it would otherwise have.

As was mentioned in the early part of this report, all except the largest rivers are sometimes entirely closed at their mouth by sand-bars thrown up by the sea, and many of the small rivers are generally in that condition. The sand-bar in all cases (except the St. John's River) projects from the eastern or north-eastern shore of the mouth, for the general set of currents and tides along the coast carries the sand in a south-westerly direction. From the maps, however, it would appear that in some years the sand-spits project from the south-west side of the rivers; such a spit for instance, is marked on the south-west side of the Kei mouth, whereas during our visit to that place a small spit ran out from the north-east side.

It is rarely that a considerable sand-dune is formed on the land behind the coast, although the wind blows enough sand from the beach inland to make the soil very sandy along almost the whole coast between the Kei and Kogha Rivers. North-east of the Nxaxo River, and north-east of the Nebbelelli River there are high hills of blown sand very scantily covered with vegetation, but in general the sand is much more overgrown than the sand dunes of the south and west coasts of the Colony. This is no doubt in part due to the greater rainfall along the eastern coast, but the sand itself seems to be blown up in smaller quantity, and the coast is more rocky in the east than in the south and west. Another point of difference is less easily explained; in the south and west of the Colony the sand-dunes often become consolidated into a sandy limestone by the solution and re-deposition of some of the carbonate of lime in them, but in the Transkei we did not see the results of any action of this sort.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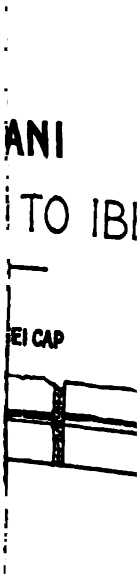
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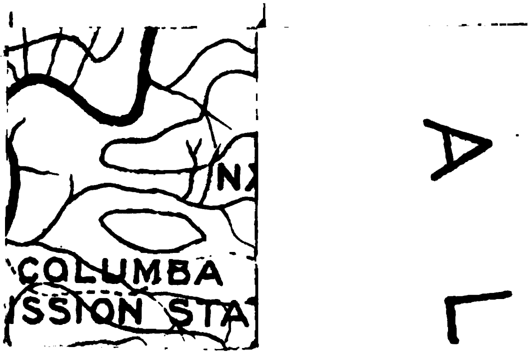
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ANNUAL REPORT

OF THE

GEOLOGICAL COMMISSION.

1902.

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A MAP TO ILLUSTRATE THE GEOLOGY OF MATATIELE

Geological Commission of the Colony of the Cape of Good Hope.

1902.

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MISS M. WILMAN.

Cape Town,
24th February, 1903.

The Hon.
The SECRETARY FOR AGRICULTURE.

SIR,—I have the honour on behalf of the Geological Commission to forward the report of the proceedings of that body for the year 1902.

These proceedings are so well summarized in the general report of Mr. Rogers, that it is not necessary that I should enter into any details.

Owing to the cessation of hostilities, and the return to normal conditions, it has become possible to resume the work of the Commission on the lines originally laid down, and it is hoped at no distant date, that the survey will be sufficiently connected to permit of the publication of another section of the general geological map of the Colony.

Owing to his acceptance of an important position elsewhere the Commission has lost the services of Dr. Corstorphine who had been at the head of the scientific work since the commencement of its labours. They take this opportunity of putting on record their sense of the value of Dr. Corstorphine's services to the cause of S. African geology and of the manner in which the initial work involved in laying out the plan of operations was carried out by him.

It is a matter for congratulation that, though no longer in this Colony, Dr. Corstorphine's scientific knowledge account of the volcanic rocks of the Drakensberg, which have not previously been described in such detail. That volcanic rocks exist in that range of mountains has long been known, but excepting a petrographical description of some rock specimens by Cohen,[1] who got his specimens and all his information as to their occurrence from the late Mr. J. Orpen, and a general description of some volcanic necks in the Stormberg District by Dunn[2], who also laid down the boundaries of the volcanic rocks of the Drakensbergen and Maluti Mountains in the third edition of his map, very little has been written about them.

The discovery of a whole series of volcanic necks in the Matatiele Division in such positions that one is forced to suspect that large parts of the Drakensberg and Maluti ranges were formerly chains of volcanoes, and that they owe their elevation to those volcanoes, is of great importance to the knowledge of South African Geology.

The results of this survey so far as it affects the uppermost part of the Stormberg Series may be summarized by saying that the volcanic activity began in this region during the deposition of the Cave Sandstone, and that thousands of feet of lava flows were poured out partly from fissures and partly from vents. The occurrence of tuffs, or fragmental rocks of volcanic origin, was found to be very local; in fact, in the Matatiele Division they are practically confined to the necks or vents which they fill. Mr. Schwarz found some fairly well preserved reptilian remains in the Red Beds, which underlie the Cave Sandstone; and a considerable collection of fossil plants was made from several places between Maclear and Matatiele. These plants will be of great help in the mapping of the Molteno Beds, in which the only workable coal known to occur in the Colony is found.

Coal was seen in several localities on about the same geological horizon as the Indwe Mines, and there is certainly a good field for the search for workable coal in the higher parts of East Griqualand; but it must not be expected that the useful character of the seams should increase as the coal horizon is followed north-eastwards from the existing mines. Until the transport of heavy loads is facilitated by railways, it is not likely that any work will be done on East Griqualand coal for other than household purposes, and even for such uses but little has been attempted in Matatiele.

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[1] E. Cohen. Ueber einige eigenthümliche Melaphyr-Mandelsteine aus Süd-Afrika. Neues Jahrbuch für Min., etc., 1875. A map showing the distribution of the volcanic rocks, based upon Mr. Orpen's information was published with this paper.

[2] E. J. Dunn. "Stormberg Coal Fields." Cape Town, 1878.

After my return from leave in August, mapping in the Western Province could be recommenced, and the greater part of the last four months of the year was devoted to a survey of the Gouph and Mordenaar's Karroo; those districts are composed of the lower part of the rocks belonging to the Karroo Systems, and an account of the geology of the area will be found on pp. .

During our journey in the Gouph, we heard of a large skeleton in the rocks near van der Byl's Kraal, and when we reached that place we found that the skeleton was on Hoogeveld, Lot A, ground which now belongs to Mr. J. P. Snyman, of Knoflock's Fontein. Mr. Snyman very kindly took us to the spot where the bones lay, and allowed us to remove them. In the matter of the transport of these bones, which weighed some 700 lbs., to our camping place, and thence to the railway, we were greatly helped by Mr. M. van der Byl, of van der Byl's Kraal. The Commission is greatly indebted to Messrs. Snyman and van der Byl for the skeleton and aid in carrying it to the railway. The bones were unpacked in the Museum in December, and cleared of their matrix by Miss Wilman, under the superintendence of Dr. Broom, who found that they are an almost complete skeleton of *Pareiasaurus serridens*, Owen. Dr. Broom has described the specimen, and his description, with illustrative plates, will appear during this year in the palaeontological volume of the Annals of the South African Museum. The skeleton itself will soon be set up in one of the galleries of the Museum.

In July of last year the Commission decided to have the fossils, collected since the commencement of the survey in 1896, named and described by competent authorities on the various groups concerned, and to have the descriptions published in a special volume of the Annals of the South African Museum, by arrangement with the Trustees and Director of the Museum. Although the collections of the survey are not handed over to the Museum for disposal, a considerable part of the South African collection exhibited in the Museum has been obtained by the officers of the Geological Commission, and the joint publication of the palaeontological work based upon the specimens belonging to the Survey and those belonging to the Museum will be advantageous t(both Institutions, and also to all who are interested in South African Palaeontology.

A collection of reptilian bones from the Karroo System, one fossil reptile from the Sunday River Beds, and several fragments from the Cretaceous Series of Pondoland, are in the hands of Professor H. G. Seely, F.R.S., of King's College, London; the plants from the Uitenhage Series and the Karroo System, as well as a few from the Cape System, are being examined by Mr. A. C. Seward, F.R.S., of Cambridge. Mr. Philip Lake, of Cambridge, has undertaken to deal with the Trilobites from the Bokkeveld Series himself, and to arrange with other palaeontologists for the examination of other groups of the Bokkeveld invertebrates. Mr. F. L. Kitchen, palaeontologist on the English Geological Survey, has in his hands all the invertebrates from the Uitenhage Series and from the Cretaceous Series of Pondoland, except some foraminifera from the latter, which Mr. F. Chapman, of the Melbourne Museum, has kindly undertaken to determine. Dr. R. Broom, of Pearston, has lately been in Cape Town, and was good enough to examine several specimens, and to describe some of them.

It is unfortunate that nearly all our collections should have to be sent out of the country for description, as, in addition to the delay, there is considerable risk of injury and loss of the specimens in transit, a risk that is greatly increased in the case of large and heavy reptilian skeletons. There is little probability of having specialists in South Africa on many groups of fossils for several years to come; at present Dr. R. Broom is the only palaeontologist in the Colony, and it is to be hoped that his services will be available to the Commission in the future as they have been during the past two months.

It has become more and more desirable, during the work of the survey, that a classification of the sedimentary rocks of the Colony should be adopted, which is unlikely to require any considerable alteration in the near future. In his introductory Report to the Annual Report of the Commission for 1897, Dr. Corstorphine inaugurated a scheme which can now be extended. Dr. Corstorphine then adopted the classification of Schenck, so far as it concerned the rocks lying between the base of the Table Mountain Series and the base of the Dwyka Series, noting at the same time the difference between Schenck's conception of the relationships of the several members of the Cape Formation (or System) and that which was held by A. G. Bain and Dunn. The latter view was held to be the correct one according to the results of the survey up to that time, and the work of the subsequent years has corroborated the decision.

The work of the past year has given us a detailed knowledge of the Stormberg Series in a part of East Griqualand, and also a much closer acquaintance with the lower part of the great thickness of rock which forms the Great Karroo, than we had before. The present occasion is therefore a suitable one for the extension of the plan laid down in 1897. The classification adopted should be at once consonant with the known facts, and capable of being amplified without undue strain by the new facts which the progress of the survey and the work of other observers are bound to bring to light.

The "Karroo Formation" of Schenck,[1] including the rocks from the base of the Dwyka Series to the top of the Stormberg, is most certainly a very convenient and well-chosen term. The Stormberg group has been separated from the underlying beds, which were divided up into "Lower" and "Upper Karroo" by Dunn[2]; but the arrangement of Schenck, which is followed by Feistmantel[3] and Molengraaff,[4] and in which the Stormberg group of rocks is a sub-division of the Karroo System of equal value to the Ecca and Beaufort Series, gives a much better idea of the relationships of the three groups than the other scheme.

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[1] "Die geologische Entwickelung Süd-Afrikas." Pet. Mittheilungen. 1888.

In the subdivision of the Karroo System we have found it convenient to separate the Dwyka conglomerate, together with the beds immediately below and above it, from the Ecca Series, an arrangement but little different from that of Dunn[5] (1887), and practically the same as Dunn[6] made in 1875.

In the subdivision of the Beaufort and Stormberg Series we have followed Seeley[7] and Dunn[8].

The rocks that are older than the Cape System and younger than the Karroo System are less satisfactorily dealt with. Schenck calls the former the "Primary Formation," which is a question-begging expression, and at the same time is now erroneous, for there are at least two, and probably three, unconformities known within that Formation; the application of the term "Primary" to the group of three or four separate, and in part at least consecutive, series of beds, is evidently wrong. The use of such terms as "Archaean" and "Azoic" is undesirable, and seems to shut out hope for future discoveries of organic remains. In the case of the South African rocks called "Primary" by Schenck, the unconformably overlying beds are perhaps the equivalents of the Lower Devonian of other countries, and some of the "Primary" rocks may eventually prove to be of the age of the Lower Palaeozoic of other countries. It is, therefore, advisable to use a non-committal term such as "Pre-Cape rocks" for the beds older than the Cape System.

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[2] Geological Map of South Africa. 3rd ed. 1887.

[3] "Uebersichtliche Darstellung der Geologisch-palæontologischen Verhältnisse Süd-Afrikas." 1889.

[4] Rapport van den Staatsgeoloog, Z. A. R. for 1897. Pretoria, 1898.

[5] Geological Map of South Africa. 3rd ed. 1887.

[6] Geological Map of South Africa. 2nd ed. 1875.

[7] Phil. Trans. Roy. Soc. Lond., 1892. B. p. 311.

[8] Report on the Stormberg Coal Fields. Cape Town, 1878

In the future a convenient territorial name may be found for them, or they may be split up into two or more systems equal in value to the Cape and Karroo Systems.

Whether the Uitenhage Series and the Cretaceous Series of Pondoland may be placed together in a " Cretaceous System " depends upon the results obtained by the palaeontologists, who have not yet settled definitely the age of the Uitenhage fauna and flora.

The deposits of more recent age than the Uitenhage and Pondoland rocks can be called " Superficial Deposits " until we have evidence that some of them contain the remains of extinct species of plants or animals.

The classification adopted here will be adhered to as far as possible in the subsequent Reports of the Survey, and also in the arrangement of the South African geological collections exhibited in the South African Museum.

			In the Transkei :—
Superficial Deposits	Dune sands, and limestone derived from them. Alluvial muds, sands, and gravels, near the present levels of the rivers. Laterite. Estuarine deposits containing foraminifera and *Cryptodon globosus*. Quartzitic rocks and ironstone gravels, representing older river deposits and laterites.		
	Pondoland Cretaceous Series. Uitenhage Series.		
Karroo System.	Stormberg Series.	Volcanic Beds. Cave Sandstone. Red Beds. Molteno Beds.	
	Beaufort Series.	Zone of Specialized Theriodonts.	Kentani Beds.
		Dicynodon Beds. *Pareiasaurus* Beds.	Idutywa Beds.
	Ecca Series.	Shales and thin sandstones. Laingsburg Beds. Shales.	Umsikaba Beds.
	Dwyka Series.	Upper Shales. Conglomerate. Lower Shales.	
Cape System.	Witteberg Series. Bokkeveld Series. Table Mountain Series.		

Pre-Cape Rocks :—

In the south and west of the Colony—

- Ibiquas Series.
- Cango Series.
- Malmesbury Series.

In the north and north-west of the Colony—

- Matsap Series.
- Griqua Town Series.
- Campbell Rand Series.
- 'Keis Series.
- Namaqualand Schists ?

Mr. E. J. Dunn has pointed out an error in the Geologist's Report for 1899, p. 17. It is there stated that Mr. Dunn observed glacial striations "on the boulders collected by Mr. T. N. Leslie." Mr. Dunn points out that the boulders were collected by himself. The mistake, which we regret, would have been corrected earlier had an opportunity occurred of doing so.

During the past year many publications have been received from various institutions and private individuals. These additions to the Library have been duly acknowledged, but the Commission takes this opportunity of thanking the donors for their journals and papers.

ARTHUR W. ROGERS.

GEOLOGICAL SURVEY OF PARTS

OF THE

MATATIELE DIVISION,

GRIQUALAND EAST.

BY

ERNEST H. L. SCHWARZ.

GEOLOGICAL SURVEY OF PARTS OF THE MATATIELE DIVISION, GRIQUALAND EAST.

The present report deals with the country immediately adjacent to the Drakensberg Mountains, in the Division of Matatiele and includes the Stormberg Beds, that is, the Coal Measures, Red Beds, and Cave Sandstone of Mr. Dunn. There are also many volcanoes, with a series of volcanic rocks, ranging from bedded tuffs and agglomerates, through lava-flows and amygdaloids to coarsely crystalline dolerites. Besides these, there are intrusive dykes and sheets of dolerite, which belong to a period of injection in which there was no outlet for the molten rock on the surface. It is evident, therefore, that the Division of Matatiele is most interesting geologically; if one also takes into consideration the people and plants that now live in the land, as well as the inhabitants in ages long gone by, the interest is by no means lessened, for, besides the Bushmen, who have now disappeared, having left their imprint in the caves in the mountains, there are a great number of detached tribes of natives, each with a long consecutive history and with their native customs still very little modified by contact with white men; there are the Basutos under several chiefs, the principal one being George Moshesh, then the Hlubis, Zizis, Zulus (Hlangwinis), and Griquas; if we add Dutch, English, and German (Trappists), it is evident that there is a sufficiently wide field in Ethnology waiting the explorer in this small district. In the plant world, on the other hand, there is the alpine flora of the mountains, the various Proteas and the peculiar native trees that still form small patches of forest in the sheltered kloofs, a field of research hardly touched.

We came to the district through Umtata, Tsolo, Maclear, and Mount Fletcher, thereby obtaining an excellent section through the country, which, added to the work done last year in the south, affords us a consecutive section from the Dwyka Conglomerate to the Cave Sandstone, from Carboniferous or Permian to, perhaps, Oolite or Upper Jurassic periods. As was pointed out in last year's report, the lower series of rocks overlying the Dwyka Conglomerate, though occupying similar positions, and containing the same fossils as the Ecca and Beaufort Beds of the west, nevertheless do not conform lithologically to those western representatives, and we had to give new names to the series in order to emphasise this difference; we found:—

Eastern Province.	*Western Province.*
Dwyka Conglomerate.	Dwyka Conglomerate.
Umsikaba Beds.	Ecca Beds.
Idutywa Beds.	Beaufort Beds.

At Umtata we have the Idutywa Beds, white chalky-looking sandstones between shaly beds that are often highly coloured in blues and reds. Along the Tsolo road there are few opportunities for studying the geology of the country, but just before reaching the village, there is a great mass of dolerite that forms the Tsolo mountain. Similar masses of dolerite occur along a line, approximately N.E., S.W., ranging from Tsolo through Mount Ayliff. They are laccolitic in nature, that is, they are enormously thick in the centre, in some cases, like the Insiswa, some 1,000—1,500 feet thick, but round the sides they rapidly thin out, and a short way from the mountain the strata have no trace of intrusive rocks included in them. The line of these great laccolites, as far as we know it, between Tsolo and Mount Ayliff, lies off the seaward face of the Drakensberg plateau, and is separated from the actual escarpment by a gap of considerable extent. Beyond Tsolo the road winds up and down over the hills to the River Inxu, having crossed which, the ascent of the escarpment is reached. A small tributary of the Inxu, the Intwyenka (pronounced Intchanka) cuts far back into the face of the cliff, and it is up this valley that the new road is made. The plateau rises about 2,000 ft. above the lower ground, the base varying from 2,100 (Umtata level) to 2,700, and the top varying from 4,300 to 4,650 (Matatiele level).[*] The Dutch have given to this line of escarpment the unfortunate name of Zuurberg, because it is like a mountain seen from the south, and because the soil is thin and sandy, and supports only the sedges and coarse grasses that grow on soils with an acid reaction. Here the Waagen-boom[†] and Sugar-bush are first seen covering the slopes of the hills in great quantities, giving to the plateaux a pleasing aspect of open park-land.

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[*] These figures are very uncertain; the level of Matatiele is given as 4,900 feet in the Meteorological Reports.

[†] These are probably the same species that grow in the same position in Natal and determined by Mr. Fourcade as *Protea hirta*, M.S., and *P. lanceolata*, E. Meyer. Report on Natal Forests, Natal, 1889, pp. 117-118.

The Drakensberg plateau, as far as we have followed it, consists entirely of Stormberg Beds, with a small number of intrusive dolerite dykes. About the head-waters of the Unzimvubu River (St. John's), however, the plateau apparently becomes injected with immense dolerite sheets, and the normal character of the country seems to be obliterated. All over this plateau the soil is poor and sour, and farmers have great difficulty in getting a patch that will even raise a little garden stuff, but where the dolerite dykes and sheets crop out on the surface, there is always some red soil (laterite) which is good and productive, so that in this way one finds nearly all the homesteads situated in the neighbourhood of the dolerite. The natives say, also, that the red soil is warmer, and they prefer to build their kraals on it. I think this is due to the amount of transpiration that goes on through the sandy, sour soil, and consequent evaporation of water at the surface, which naturally produces cold, whereas the compact clayey laterite does not give off water-vapour, so that at nights the heat absorbed during the day is dissipated slowly, and is not neutralised by the conversion into vapour of water held up in the soil.

The Molteno Beds of Green correspond to Dunn's "Coal Measures"; they consist of shales between banks of coarse sandstone; this latter is made up of clear limpid quartz, often showing crystal faces and even perfect pyramids, with more or less felspar and a little mica. The fractured surface of the quartz-grains reflects light strongly, and masses of the rock glisten in the strong sunlight as if the surface were set with cut stones; hence the name Dunn gave to this rock of "glittering sandstone." This same peculiarity* is noticed in the Hawkesbury Sandstone of Australia, which is similar to our Table Mountain Sandstone, in that it consists of a massive series of false-bedded sandstones, 1,000 feet or so thick, but which lies above the productive coal measures, and corresponds in age to our Stormberg Beds. The rock in Matatiele is usually massive, and forms beds two or three feet thick, which disintegrate on the sides of the kloofs into immense slabs. Many kloof-sides are just one jumble of these great blocks, which are ingeniously utilised by the farmers, who take a great slab of a convenient thickness, and run in a series of iron wedges in a row, each wedge being driven in for about two inches; then on giving the stone a blow, a rough column is broken off and the process repeated, each slab affording five or six columns from 4 to 6 feet long, which answer admirably for fencing poles. Owing to the extreme scarcity of wood in these parts the farmers would be badly off for poles if it were not for the sandstone being so well adapted for the purposes. The sandstone in the Molteno Beds is also useful for building, being so easily trimmed, and examples of its use are exhibited in the Maclear and Ugie Bridges, both made entirely of stone from the neighbourhood. The usual colour is creamy white, but it is often tinged grey with carbonaceous particles and sometimes contains actual beds of coal. All grades of fineness can be seen up the Intwyenka cutting, and near Maclear village some very coarse varieties are met with, which have more the appearance of a pegmatite granite than of a sedimentary stone. In between the banks of sandstone there are muds of various kinds, sometimes yellow or bluish, sandy clays, unlaminated, with fern-fossils irregularly distributed, or again they may be brilliant blue, white and red clays, and thirdly they may be blue-grey or black laminated shales of all degrees of fineness of lamination often with layers full of fossil ferns and in places with coal. Dunn states that in the Stormberg area the "coal measures" are distinguished from the beds above and below by the absence of these bright coloured clays, but in the Matatiele Division one can see the coal measures in one kloof, with fern fossils, and in the next kloof the section will show only brilliantly coloured clays, red, blue and white.

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* Ch. Darwin, Geological Observations, 1851, Pt. II, Geological Observations on Volcanic Islands, p. 131.

Maclear is a very good place for studying the Molteno Beds in their typical aspect, and there are many points round the village which are specially interesting. Coal has been dug in considerable quantities from the north bank of the river, and has answered admirably for the purposes to which household coal is put. It is very variable in quality, however, and the seams grade into coaly shale. In the road-cutting leading out from the village northwards, there are several coaly seams exposed, one, however, is very interesting. It occurs near the top of the hill, and the seam is in sandstone. Near by there is a dolerite dyke, and the sandstone has been cracked, evidently as a direct result of the dolerite intrusion. One of the cracks runs down through the sandstone into the coal seam, and the space left gaping, about an inch in width, is filled in with coal. Here, then, we have undoubted proof that under the influence of heat derived from injected molten rock, and also probably of water circulating through the rocks, coal can be taken from its original seam and deposited in cracks in the neighbourhood. This was my explanation of the occurrence of the Beaufort West coal. There there is a vertical crack of considerable extent filled with coal, and the only true seams to be found are a number of thin beds varying from half an inch to an inch in thickness. These I took to be the source of the coal in the crack, for when the dolerite that occurs so plentifully at that spot, was intruded, the water in the rock became intensely heated, swept out what coal there was in its path to the outer surface, and deposited it in the crack. The difference between the Beaufort West occurrence and the Maclear one is, that in the two cases the proportions between the size of the seam and the crack are reversed. At Beaufort there is a big crack and very small seams, in Maclear a big seam, while the crack filled with coal is small.

To the west of the village of Maclear there is a hill, really the continuation of the plateau of which the sandstone with coal is the defining bed. At this locality the sandstone is well exposed in ledges with small caves beneath. At the base of the krantz, the sandstone is full of very well-preserved ferns, of which *Thinnfeldia odontopteroides* is the most abundant. The latter fern is found in every part of the Molteno Beds, and can be easily recognised from the fact that it usually divides in two, a short way up the frond, and otherwise has no branches.

About two miles from Maclear on the Ugie road there is a very fine example of an upright stem exposed in a road-cutting; the rock in which it occurs is grey sandy clay, and the stump is about 15 inches in diameter and about two feet long; on the lower side there are two roots coming off at an angle of 150° between them. The wood is silicified, but the outer casing is carbonised.

Coal-seams similar to those at Maclear can be seen in the road-cutting as one nears Mount Fletcher from Maclear; they consist of coaly seams in the shales, and patches of coal in the sandstone. Beyond Mount Fletcher, at the Tina Drift, there are great numbers of *Thinnfeldias* and whole layers filled with reed-like bodies, one species coarsely, the other finely fluted.. A larger amount of dolerite than usual occurs in the neighbourhood of Mount Fletcher.

MATATIELE SEDIMENTARY BEDS.

In Matatiele we have to deal with the same beds as those just described, but in the work undertaken by the survey party, which was mostly under the mountains, the higher beds of the Stormberg Series* were principally investigated.

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* This name was first used by A. Wyley, Notes of a Journey in Two Directions across the Colony, Cape Town, 1859, p. 11; it was also independently suggested by T. H. Huxley, Q.J.G.S., Vol. XXIII., 1867, p. 5.

According to Dunn, the succession above the Beaufort Beds is as follows, from above downwards:—

Volcanic Lavas.
Cave Sandstone.
Red Beds.
Coal Measures.

In this report Green's term " Molteno Beds "* will be used for the " coal measures " of Dunn, as the latter term is too ambitious for the particular set of beds.

In Matatiele the Molteno Beds are well defined at the top, so that one is seldom in doubt as to the upper limit of them. The entire thickness would be about 2,500 feet. It is quite different, however, with the two succeeding divisions of the sedimentary rocks. In some places the two series can be well recognised, at others the Cave Sandstone is plainly absent, and in still other places it is impossible to decide whether they are two series or one, and to which particular series, if there is only one, the beds in question belong.

The sedimentary beds in Matatiele have an absolute dip to the north-west, but this dip is made up of two components, a drag due to the falling in of the line of volcanoes after their activity had ceased, which, as we shall afterwards see, produced a dip to the N.N.W., and another drag, whose origin we do not yet know anything about, which depressed the beds in a direction parallel to the volcanic chain, reaching its culmination, as far as we have seen, at Ongeluk's Nek. The strata are very nearly horizontal, and appear to be quite so owing to the smallness of the dip. There are no folds developed in the rocks, except in one place, between the Kenigha River and the village, where there is a gentle syncline, and the river runs through the centre of the arch of the anticline formed by this syncline and the general dip of the strata. There are several faults along the Kenigha, especially about four miles south of Nehemiah's Drift, but the fault-faces are usually separated by a dolerite dyke, so that it is probable that the intrusion of that rock and the dislocation were closely connected in origin.

The general arrangement of the sedimentary beds, therefore, in Matatiele is for the Molteno Beds to occupy a larger area in the east; while in the west, the higher beds being depressed, they occupy, I will not say a larger area, because so much has been removed by denudation, but a more conspicuous proportion.

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* A. H. Green, Report on the Coals of Cape Colony, Cape Town, 1883, p. 6.

In the following description we will take the beds from the east to the west.

The most eastern point of the ground surveyed was on the borders of the Inhlangwini location. This lies on a spur of the mountains separating two areas, each forming a gathering basin for the Umzimvubu (St. John's) River. The valleys under the Drakensberg are divided all along into compartments by means of high spurs, and this makes it difficult to get about. Each basin is divided up into farms, unless it is a location like the Inhlangwini one, and the farmers in the one area are practically shut off from those living in the neighbouring basin.

The first basin is marked on the maps still as " Vacant Location reserved for farms," but it has been surveyed, and the farms sold some two years ago; it also includes a few of the original farms that were allotted to the Griquas in the first settlement of the country, but this people never seem to have recovered from being removed from Griqualand West, and they have disappeared from these parts.

The basin consists of two levels, the lower one separated from the upper by the steep escarpment of a plateau lying a thousand feet above. The upper plateau and the face of the escarpment are deeply cut into by the streams from the mountains, and most wild, precipitous and narrow gorges are produced. The lower level is altogether different, and shows evidence that the downward sawing of the rivers had been arrested, for they take on most complicated bends and windings. The cause of this has been the horizontal dolerite sheet that traverses the strata here; the rivers now have actually cut through the sheet, and the rapid downward erosion has commenced again; owing, however, to the resistant nature of the dolerite, these bends are perpetuated, and the rivers are not able to get out of the crinkles that they formerly made for themselves, and in the lapse of time the complicated winding gorges will be formed which are so common nearer the coast, for instance, in the " Collywobbles," near Idutywa.

The following farms lie in the lower level of the particular basin we are describing:—Part of Sibi's Location, Prospect, Richmond, Nuhah, The Bends, Otterburn, North Brook, Hillside, Afzondering, N'quabo, Nahainkwe, Rochdale, and the new farms N'kadi, Tikatikong, Carl's Ruhe, and New Rush. On the west, south-west and east the basin is cut off from the rest of the country by very high steep hills, whose tops were once in continuity with the plateau above, but the head streams of the Umzimvubu have cut down through the plateau and removed the material, so forming the basin of the lower level. The hills are capped with an immense krantz of sandstone which belongs to the Red Beds; on Kroon Hoek and Lange Punt, two farms on the southern side of the dividing ridge, it has afforded a good deal of coaly matter, probably existing in the form of small pockets. A short way up the hill-side, there is exposed an extensive sheet of dolerite, dipping slightly to the west, but very irregular in its form, sometimes bifurcating into two sheets, one above the other, and at others undulating and forming troughs. The sheet is well exposed along the Little Umzimvubu, and seems to increase in extent and thickness southwards, towards New Amalfi, but it was not followed in that direction. Northwards, it thins out, and though a great part of the end of the sheet is buried in the hill-side, yet on N'Kadi and Tikatikong it can be traced thinning out to nothing. On Afzondering it appears bent, and a small hill along the Little Umzimvubu is riddled with small dykes that come off it. Some of these dykes are of unusual composition. Through Afzondering, Nahainkwe, Rochdale and New Rush there runs a very striking double dyke of dolerite, in a direction 25° N. of W., dipping 60° to the S.W. The two dykes are separated by about 100 yards, and produce by their weathering very peculiar amphitheatres at the mouths of the gorges on Nahainkwe and New Rush. On Nahainkwe and Rochdale there is another sheet, thin and irregular, forming ledges a short way up the hill-sides.

On the north side of Nahainkwe, under the dolerite sheet, there is a coal mine that formerly supplied coal to Kokstad and district, but has not been worked for some time. The following section taken at the mouth of the eastermost of the tw drives will give some idea of the nature of the occurrence:—

		Ft.	In.
12.	Krantz of Molteno sandstone on top.		
11.	Grey shales, thinly laminated and carbonaceous.		
10.	Grey sandstone	0	1
9.	Carbonaceous shale, thinly laminated	2	11
8.	Drab sandstone, with large white mica flakes	0	4
7.	Carbonaceous shales	1	6
6.	Coal	0	9
5.	Drab sandstone	0	3
4.	Coal	1	0
3.	Compact carbonaceous shale, "splint" or "torbanite"	1	2
2.	Laminated shale, highly carbonaceous	2	3
1.	Grey shales with much iron	0	10
	Blue shales and sandstones.		

The coal is laminated and of very varying quality, but with hand-picking should afford a very useful coal for household purposes. No. 3, however, is the most interesting occurrence in the mine. It forms the floor of the seam, and the coal is stripped off it, and the " splint" left behind unless the tunnel is too low, when the splint is easily stripped in layers. It is not a true coal, and not even pure enough to be torbanite or boghead coal, but it belongs to the same nature of mineral as the latter. It is apparently a mud that has become charged with carbonaceous material when stagnating under the waters of a lake. As there seems to be a good deal of doubt as to what kind of mineral this is, the following description of the type occurrence may be useful.

The torbanite of Linlithgow occurs associated with several coal seams, and with them occupies a small mineral basin about three square miles in area. These coal seams and the particular bed itself are interstratified with two or three beds of fresh-water limestone. It yields 120 gallons of crude oil per ton, and has been largely used for the production of paraffin and its products. It was used under a patent by Mr. Young in the year 1850, and Young's paraffin oil, which gave the start to the use of mineral oil lamps in England, was made from it. It should be borne in mind that in the litigation that ensued relative to this mineral that it was laid down in law that it was a coal, although the bulk of the evidence went to prove that it was rather a bituminous shale or clay. To avoid litigation over this mineral in the Stormberg, therefore, clauses should be inserted when drawing up mining contracts, clearly stating whether this mineral is included or not.

Dunn in his 1873 Report on the Stormberg Coal, mentions torbanite as one of the things he expects to find in the area, but up till then he had only found something like it between the coal in the seams round Molteno. Mr. H. E. R. Bright, however, also in 1873, in the Cape Monthly Magazine, described an occurrence of such material in Basutoland in the angle between the Great and Little Caledon Rivers, near Maseru. Mr. Bright gives in the paper the following section:—

	Ft.	In.
Reddish quartzose sandstone	2	0
Shale, blue grey	0	2
Splint (*i.e.*, the torbanite)	1	0
Shale, blue-grey	0	6
Red quartzose sandstone, bed rock	0	6

The following is an analysis of the Matatiele mineral kindly made for the Commission by Mr. J. Lewis of the Government

Analytical Laboratory, compared with the analyses of similar minerals:—

		I.	II.	III.	IV.
Moisture	1·32	34·00	33·	70·10	·16
Volatile Organic Matter ...	18·16				89·59
Fixed Carbon	32·37	16·66	22·	10·30	5·27
Ash	47·26	49·34	45·	19·60	4·98
Sulphur	·89	...	...	...	·38
	100·00	100·00	100·00	100·00	100·38

Nos. I. and II. are analyses given by Mr. Bright in the paper above referred to of the "splint" from Basutoland, and No. III. is an analysis of the Torbane Hill mineral given by Davis in "Earthy Minerals." No. IV. is from Joadja, New South Wales, and is given by Pittman in the "Mineral Resources of New South Wales," 1901.

Mr Lewis reports that 100 grams of the Matatiele rock on distillation yielded:—

Watery distillate	3.33 grams.
Tar	10.00 grams.

Approximately this means 25 gallons of oil to the ton, as compared with the 120 gallons to the ton in the Torbane Hill mineral. The Joadja torbanite yields 130 gallons of crude oil, or 15,399 cubic feet of 48 candle gas per ton. The South African samples do not therefore compare favourably with those from other countries, but on the other hand, one must remember that the country in Matatiele is hardly occupied yet; 25 years ago Dunn was urging that white settlers should be allowed to go into the country, as there was great likelihood that coal would be found there; the settlers are there now, but all the prospecting has yet to be started, and there is every probability that better seams of coal and torbanite will ultimately be found.

The following (No. 1) is Mr. J. Lewis's analysis of the coal occurring on top of the torbanite:

	I.	II.
Moisture	1·37	12·54
Volatile Organic Matter	24·68	
Fixed Carbon	47·53	63·03
Ash	25·10	24·42
Sulphur	1·33	...
	100·00	99·99

No. 11 is an average of three coals from Indwe for comparison. The ash is almost the same in the two cases; in the three samples given by Dr. Hahn (Report on Indwe Coal, Cape Town, 1884) the ash varies from 11.08 to 28.87 per cent.

Taking away the ash, the percentages of fixed carbon are:—

Matatiele, 63.31. Indwe, 83.42.

The Matatiele mineral is a low-grade coal, but then all the Stormberg coals are low grade; it is, however, a useful household coal, burning freely, owing to there being a larger percentage of volatile hydrocarbons than is found in most of the others.

Coaly seams crop out in many places throughout the district, and there is every possibility that larger seams and of better quality than the one already exploited are to be found, but so great is the amount of débris that covers the hill-slopes that the chances of striking on any such seams by the method of ordinary prospecting are not very great, but with extensive boring, there is a great deal to be expected.. Certainly all the seams we had an opportunity of seeing were poor, and the character of the rocks are such as to preclude the idea of any great and far-spreading seams, but workable seams are sure to be found. The question of coal is an important one in these districts, as natural fuel is very scarce, and consists of a limited quantity of Proteas; the inhabitants, both native and white, use almost exclusively the ox-droppings. The Stormberg rocks afford at the best a very poor and thin soil, and this systematic picking up of every particle of burnable material—the natives quarter the ground like a hawk after its prey, and not a square yard is unsearched—is taking away from the soil its natural manure, and the consequences to the district in future years will be serious.

The upper level of this basin includes the new farms, Cort's Retreat, Hermitage, Etchell Berg, Edward's Hope, Farewell, Phelan's Brook, Robert's Vale, Joe's Luck, Ramkakala, Mount Fred, Harry's Gorge, Maseru, Mangalore, Tiger Valley, and Zureka.

The western side is formed of a high ridge, capped with white sandstones, belonging apparently to the Red Beds, as they are in a way different from the Cave Sandstone above, and from the Molteno Beds below. The Molteno Beds include the usual coarse sandstones; in addition to the quartz, felspar, and white mica that can be found everywhere, there are also garnets. I was unable to find any of the last *in situ*, but on Edward's Hope there is a small stream rising in the Molteno Beds, and entirely cut off from other formations, in the bed of which, by careful washing, a number of blood-red garnets were obtained.

The shales between the sandstones are very varied, consisting of red and blue muds, sandy clays with beautiful fern impressions, and a little black shale. Coal occurs on this higher level, but no big seam has been found; what has as yet passed for coal seams are the patches of lignite in the clays. In these latter beds one finds tree-trunks, sometimes merely blackened with extreme age, and retaining all the cellular structure of wood; at other places the ligneous material is replaced by black stone, and only the external features of wood remain. On Edward's Hope, about a mile north of the house, along the stream bed, there is a bed of apple green clay, which looks glauconitic, but which, under the microscope, is seen to consist of scales of some light greenish-brown mineral, without the sign of any organic remains.

The sandstone krantzes in this part of the basin are very striking, dividing the country into plateaux. The krantzes surround the plateaux with cliffs sixty to one hundred feet high that are scalable at only one or two points. The dolerite dykes that occur sparingly hereabout cut through all the beds, and form passages from one plateau to the other. A good instance of this occurs along the farms Etchell Berg, Farewell, and Hermitage, the dyke running E.S.E. At Robert's Vale above the house there are two more in about the same direction. On Mangalore there are again two parallel dykes deflected more to the east, the more northern one forming a sharp ridge, which has been taken for the northern boundary of the farms Tiger Valley and Rochdale; it bifurcates at the eastern beacon between Mangalore and Maseru to send a branch which runs nearly along the eastern boundary of Maseru.

In the upper portion of Tiger Valley and Zureka there is a dolerite sheet about 20 ft. thick, intercalated between the Molteno Beds. It crops out on the steep slopes of the river valleys, and is perfectly conformable to the beds above and below. The dolerite dykes cut through the sheet in the same way as they do the sedimentary rocks, but there are no sections where one might settle the question whether this is contemporaneous lava flow or an intrusive sheet. In extent, as far as I saw it, it was between four and five square miles. The same uncertainty applies to a sheet in a still higher level, which, on the east of Zureka, overlies the Molteno sandstone, but in the middle of the farm is between the Red Beds and Cave Sandstone. This, if the beds were normal, would indicate an intrusive sheet, but knowing how irregular they are, and how difficult it is to distinguish with certainty any of the three series, it would be unsafe to draw any conclusion as to the nature of the dolerite sheet from these considerations. There is a third mass of dolerite above this last sheet connected with the amygdaloidal lavas which we shall treat of when dealing with the Drakensberg amygdaloids.

For the rest, the upper level is divided into mountain farms, which include portions of the actual mountains with the sweet veld that grows on the amydaloids and the débris washed down from them; and the plateau farms, that, except for the alluvium along the rivers and the spare dolerite dykes, are made up of rugged gorges, plateaux with dangerous krantzes all round, and steep hill-slopes covered with immense blocks of sandstone; the soil is sour, with coarse grass and sugar-bush growing upon it. The Red Beds and Cave Sandstone belonging to this area will be described separately in the following pages.

The second basin is a more straggling one than the last, and includes the head-waters of the Kenigha. This river rises on the east peak of the Twins, and runs eighteen miles to the east by south, turns sharply south for a few miles to circumvent the spur that shuts off its compartment under the mountains from the one further west, then goes west for seven miles, meets the Mabele, the river that drains the next compartment coming eastwards, and then turns again sharply south, and leaves the Matatiele Division in that direction. This is such an unnatural arrangement that one looks for a possible explanation. The general trend of the rivers is to the south-east. Here we have two rivers starting normally in the general direction, then joined up most unnaturally by cross courses to the south. We have already seen that the lower course runs in the axes of an anticline, and I think that there is very good evidence that the disarrangement of the river system was produced by these north and south folds which belong to the system of folding that prevails further east in Natal; the Matatiele fold would be the most inland member of that system. The folding, which, it must be remembered, is always gentle in the east as opposed to the intense action in the west of the Colony, must have occurred after the eruption of the volcanoes and after the greater portion of their substance had been denuded away, but it does not prove that all the north and south folding of the eastern part of South Africa was of that period.

The second basin is naturally the area of drainage of the upper Kenigha. As the river runs towards the east by south it receives all the torrents that course down from the mountains, each torrent forming a little bay for itself. From west to east, as the Kenigha recedes from the mountain, so the bays become larger. The first three bays under the Twins are in Maklagala's country (Hlubis); the fourth bay contains the farms Retreat and Makomereng; the fifth Glen Alfred and Deer Park; the sixth, Tramore and Dell Cranney; the seventh, De Schuur, La Grange, and Bramwell; the eighth, Mont Plaisir, with Mafube Mission Station, Rolland, The Paddock, Belfort, N'Quatsha, Eyrie, Uplands, Rheebok's Rust, and Woodlands; and the ninth, the greater part of Sibi's Location (Basutos). The whole basin is self-contained, and separated from the flats around the village of Matatiele by a ridge of sandstone; from the Mabele valley it is separated by a long spur of the Drakensberg, ending near Moteries Kop. This ridge has many points of interest attached to it; at Moteries Kop stood the old Residency where Mr. Brownlee was besieged in the Basuto war; it was here also that the famous Matatiele meteorite was found, while further north there are three volcanoes. There is a good deal of white sandstone on the ridge, some of which is undoubtedly Cave Sandstone, and there is a very large expanse of Red Beds as well. The Molteno Beds in this compartment play a much less conspicuous part than in the first one, though they form the plateaux that stand out like steps to the main crest of the mountains. The sides of the steep river valleys are ruled, as it were, with the krantzes of Molteno sandstone, each krantz following the contours of the slope, and exactly parallel to the one above, and all separated, except towards the top, by an equal interval of shale, of about twice the thickness of the sandstone. Above these come the Red Beds, with their sandstone; then come indeterminate beds, and finally the chalky-looking Cave Sandstone, in immense solid banks.

The following section will make clear the relationship of the various members of the Stormberg Beds. It is taken from the eastern part of Deer Park:—

Cave Sandstone, 132 ft.*	Massive white sandstone	12	feet.
	Laminated white sandstone ...	18	„
	Massive white sandstone ...	12	„
	Red marl (elsewhere massive sandstone)	60	„
	Massive white sandstone	30	„
Red Beds, 200 ft.	Red clay with three thin sandstone beds towards the base ...	90	„
	Massive white sandstone	20	„
	Red clay with occasional bed of sandstone	90	„
Molteno Beds, about 2,000 ft.	1. Massive sandstone, glittering and weathering black	25	„
	Grey-blue clays and shales ...	60	„
	2. Massive glittering sandstone ...	20	„
	Grey-blue clays and shales ...	40	„
	3. Massive glittering sandstone ...	20	„
	Grey-blue clays and shales ...	40	„
	4. Massive glittering sandstone ...	20	„
	Clays and shales	40	„
	5. Massive glittering sandttone ...	20	„
	Clays and shales	40	„
	6. Sandstone	20	„
	Clays and shales	40	„
	7. Sandstone	20	„
	Clays and shales	—	

No fossils were obtained from the Stormberg Beds in this basin, the sides of the hills are covered with fallen blocks of sandstone, and the river-courses are generally lined with débris from the mountains, consisting of coarse gravel, made up of amygdaloid boulders, so that a section suitable for looking for fossils is rarely afforded.

There are a few dolerite dykes in this part of the country, one very long one crosses over from Basutoland and runs south-east through the north-east side of Belfort and through The Paddock. On Glen Alfred there is another small one, trending S.S.E. These two, with the ones in the basin first described, seem to radiate from an area of disturbance in Basutoland, for if the lines of the dykes be produced, they all meet within a mile of each other, along the Orange River, north of the western peak on Makomereng. On Retreat there are three dykes running parallel to each other in an east and west direction. The central one is very unusual in character, for the northern walls shows intense crumpling. The dolerite has sent off little dykes between the sedimentary rocks, and on the other hand, the dolerite has evidently torn off pieces of the wall, and included them in its substance. These bits are now turned to porcellanised shales, with cracks filled in with quartz and calcite. On the south side of the dyke the rock is compact and intensely tough. On the contact with the south wall, there is evidence in the form of slicken-sides of a rubbing motion having occurred, and of the two sides having opened gradually, for minerals are deposited between. Owing to the peculiar form this manner of deposition has induced in the minerals, making them appear at first sight to be fibrous, the deposit is locally known as Asbestos; the minerals seem to be calcium and strontium carbonates. Other than this, there is no sign of anything abnormal on the south side of this dyke. I am inclined to think that the tearing and crumpling that has gone on on the north side is evidence that there was a free exit for the rising magma at the surface of the ground, which allowed an explosive action to take place.

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* Mr. Dunn, in the Stormberg area, gives the following thickness for the various beds :—Cave Sandstone, 150 feet ; Red Beds, 600 feet ; Molteno Beds, 1,000 feet. Report on the Stormberg Coal Fields, Cape Town, 1878, p. 4.

The third basin is entirely in Native hands, comprising N'kau's and George Moshesh's Locations (Basutos). Most of the spurs are made of Red Beds or Cave Sandstone, and the Molteno Beds only enter into the southern parts of these ridges. A great part of the Molteno Beds also is covered with alluvium, so that these appear less even in extent than they are. In the fourth basin, drained by the upper reaches of the Mabele River, the Molteno Beds do not appear at all, the country being made up of Red Beds, Cave Sandstone, and amygdaloid.

Turning away from the mountains, the whole country is composed of Molteno Beds, always with a few dykes and intrusive sheets of dolerite to save the veld from universal sourness. The dolerite begins feebly in the west, but there are considerable quantities near Matatiele, especially in the mountain behind the village. The peculiarity of these sheets and dykes is the irregular course of both; a sheet crops out at half a dozen different levels, and at no one of them is it of any great extent; dykes run for a short distance, and end abruptly or expand into knobs. This is quite different from the mode of occurrence of the Karroo dolerites, that with their sheets cover thousands of square miles with very little variation in level or thickness, and the dykes are always definite off-shoots of a sheet or have a long course of their own. And it is quite different, also, from the way the laccolites are intruded further south. A peculiar horseshoe-shaped dyke occurs on the farm Upsala, which is described petrographically at the end (slide No. 953), but it is here interesting to note that these annular dykes are not infrequent (see Dunn, Report on

Stormberg Coalfield, 1878, p. 15). Further east, there is a very large area of dolerite in immense sheets, but the survey was not carried over the area sufficiently widely to allow one to get an idea of its bearing on the structural geology of the district.

There is a surface deposit that is found on the Stormberg area that is of great interest. It is the same as some forms of so-called laterite, such as one gets further south on the coast plateau, and is familiar to people in Cape Town as the "saarverig" or ironstone gravel that is used for the roads on the Cape Flats. This deposit, however, is not like laterite in the way it forms. It occurs in thick beds, looking like cindery slag, with rounded brown knobs and hollow spaces filled in with yellow oxide; it is usually taken to be volcanic. It is formed in the same way as that at the Caledon Springs, where water charged with iron salts oozes through the rocks and evaporates, leaving the hydrated oxide of iron behind. In Matatiele, where one finds the deposit, the soil is very sour, for instance, on the west of Mafube Mission Station, and by the vley on Alwinrein. It appears necessary for the precipitation of the material that the water containing the salts in solution should come in contact with organic acids. Acidity in the soil is due to want of aeration, and occurs mostly in soils that become water-logged, so that it may be only accidental that the sour veld is found at the same places as the ironstone gravel. For some obscure reason it has been taken to be a sure indication of coal, and ideas of this sort that have grown locally are exceedingly difficult to combat*

The RED BEDS and CAVE SANDSTONE were defined by Dunn, the author of the terms, as follows:

ave Sandstone.—Buff coloured, pinkish, greenish white and grey, fine-grained, thick-bedded sandstone.
Red Beds.—Friable and arenaceous shale; do. sandstone, mottled green, alternating with grey felspathic sandstone.

In Matatiele I had great difficulty in making a division between the two, because their characters change so very often and the relative thickness of each also varies. Normally the Cave Sandstone in this district consists of massive white sandstone, more like a trachyte tuff than an ordinary sediment; under the microscope, however, it shows grains of microcline. The Red

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* See the description of the same kind of deposit which forms under sandy soil in Wolmer "forest," Gilbert White, The Natural History of Selbourne, Letter iv., 1st Series.

Beds are distinguished by the red clay, which predominates everywhere, and in this district by a bed of sandstone in the centre, which is not as chalky-looking as the Cave Sandstone, yet not as crystalline as the Molteno sandstone. The chalky appearance of the Cave Sandstone is due to the nature of the quartz grains, which are irregular, rounded grains, with a rough surface; in the Molteno Beds the grains, on the contrary, if not actually crystals, are in miniature water-worn pebbles of quartz, and this bed in the Red Beds is midway between the two varieties, that is to say, between "glittering" and "chalky." The Cave Sandstone is sometimes replaced by red clay, often mottled with green, or alternating with light blue clay. The percentage of quartz grains in this rock is enough to make it a sandstone, but its surface features are those of a hardened clay.

I give below some analyses kindly made for me by Mr. J. Lewis, of the Government Analytical Laboratory. No. I. is Cave Sandstone, from N'Quatsha's Nek. No. II. is a light greenish blue sandstone, from the Red Beds below the last. No. III. is a typical sample of the red clay that occurs in the Red Beds and Cave Sandstone; the specimen comes from the ridge on the west of the western kloof on Glen Alfred, and replaces Cave Sandstone:—

	I.	II.	III.
Silica	83.52	77.27.	74.04
Calcium oxide	.67	2.33	2.28
Sodium oxide	1.55	2.10	3.04
Potassium oxide	1.44	2.58	2.36

Taking No. I., and calculating the amount of felspar the Calcium, Sodium, and Potassium oxides represent, supposing that there is an orthoclase present with a Potassium-Sodium ratio of 14.4/3, and that the plagioclase is an oligoclase with a ratio Ab/An of 4/1, one gets:—

Orthoclase	10	per cent.
Oligoclase	13.3	"
Kaolin	13.9	"
Free quartz	62.8	"
	100.0	

which gives a calculated composition for remaining constituents as follows:—

Silica	83.52	per cent.
Calcium oxide	.67	„
Sodium oxide	1.55	„
Potassium oxide	1.44	„
Aluminium oxide in the felspars	5.06	„
Aluminium oxide in the clay ...	5.04	„
Water in the clay	2.72	„
	100.00	

This analysis shows at once that the silica content is too high for the rock to be a tuff of the kind its texture would lead one to expect. The rock is a felspathic sandstone, though the felspar rises to nearly a quarter of the whole amount, and if one adds the kaolin, which is decomposed felspar, it amounts to one-third.

The Cave Sandstone may be one of two things, either the consolidated detritus of a granite region, or it may be the result of the accumulation of material blown out of the vents of the volcanoes, and derived from the shattering of rocks deep down in the earth's crust, and below the region of the later sedimentary rocks. The fact that the material plugging up the necks is identical in nature with the Cave Sandstone, even to the presence of the minute accessory minerals, especially zircon, is strongly in favour of the latter view, We shall see presently that there is good evidence that the last stage of some of the volcanoes was certainly explosive, and if we adopt the view that the Cave Sandstone is also the result of the same action, we must conclude that in Matatiele the initial stages were confined to clearing and enlarging the vents for the subsequent flows of lava. The least depth at which the pre-Cape or granitic rocks can exist below the Cave Sandstone is 10,000 feet, but the great amount of felspar in the Cave Sandstone indicates that the vents must traverse the pre-Cape and granite rocks for a greater distance than this.

Nos. II. and III. are remarkable owing to their large alkali content, that of Potassium in particular. They have, in this respect, more the composition of an andesite than of a sedimentary rock. No. III. effervesces slightly with acid, so that some of the calcium is in the form of carbonate, which in thin sections of the rock is seen to occur as a cement to the grains.

The analysis of these rocks is in favour of the conclusion that the Cave Sandstone and Red Beds are made up of materials that in part at least, owe their origin to the volcanic outbursts. Many of the necks are filled in with material, evidently the same as the Cave Sandstone, yet having in itself nothing to do with volcanoes. In the volcanic regions of Shetland, Firth of Forth, the Eifel in Germany, and many other places, there are similar necks filled in with non-volcanic rocks, but in most cases there are volcanic tuffs accompanying them; these were small vents which stopped working in a very early stage of their existence; some of them never even poured out a single stream of lava. The composition of the rock in the necks is explained by the purely explosive action in the vent, sometimes blowing through molten rock and producing tuff, at other times simply blowing a hole through the sedimentary rocks and filling the neck with the shattered materials.

Dunn found in the Stormberg area that in the Coal Measures (Molteno Beds), apart from the Red Beds, that there were no red or blue coloured rocks, but I found in Matatiele that the red and blue clays were equally well developed in the Molteno Beds, as in the series above.

Organic remains are very scarce in these beds, though they occur plentifully in other places in the neighbourhood.* Dunn found reptilian bones in both Cave Sandstone and Red Beds. I was only able to obtain them from one locality in the latter series. This was at Makomereng, both on the east and west sides of the stream. On the west side there is a ridge running south, which near the mountains is capped with amygdaloid and Cave Sandstone, but the terminal portion consists of Red Beds; at the end there is a kopje crowned with the Red Beds sandstone, and between it and the rest of the ridge there is a nek in the red clay of the series; sparingly distributed through the clay there are numerous detached bones, but as the rock splits up into fragments on the surface, there is very little hope of getting anything very satisfactory from the beds. Above the house on Makomereng, on the east of the stream, there is a similar arrangement of the beds, and beneath the sandstone krantz there is a small cave, on the floor of which was exposed some bones, which proved to be the foot of some large animal. The tibia, some of the tarsal bones and all the metatarsals and phalanges were present. The rock is exceedingly tough and difficult to work with a pick, and one can do very little with hammer and chisels, as only small bits can be got out at a time. The animal has been gradually weathering out, and for some years past bits of it have been obtained and distributed. There are small bits of charred wood along with the bones.

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* Basutoland, Long, Scientific African, Cape Town, April, 1896; Nelson's Kop, Harrismith, O.R.C., Anderson, 1st Ann. Rept., Natal, 1901, p. 89; Dunn, Report on the Stormberg Coal-fields, Cape Town, 1878.

On the east side of Eyrie, in the Cave Sandstone, there are some indistinct remains that look as if they might be organic; these consist of little tubes with a central style and septa, like in an *Orthoceras*, but much too irregular to be the remains of that animal.

On Ramkakala in the Red Beds there were some peculiar formations that one would take at first sight for bones. They consist of a hard outer siliceous wall and an interior medullary tissue, but the tissue is far too irregular for bony tissue; possibly they are bits of wood that have been charred and siliceous material has run in and filled in the cracks; afterwards the charred material in course of time disappeared.

The distribution of the Red Beds and Cave Sandstone follows the distribution of the volcanic vents in the Drakensberg; where the latter are present, there is the greatest development of Cave Sandstone; where the volcanic vents are absent the Cave Sandstone becomes irregular or absent, and the Red Beds take its place.

Between Mount Fred and Ramkakala there is a stretch of hillside with no Cave Sandstone, but from the farm Maseru eastwards this bed begins again, at first only thin, but broadening out on Zureka, and continuing eastwards into the Inhlangwini Location. From Belfort to Zureka no volcanic vents were observed, and this corresponds with the thinning out of the Cave Sandstone. Whether the peculiar rocks on the crest of the Drakensberg at Zureka represent a volcano, I was unable to make sure, but am inclined to regard them as outbursts from a volcano on the Basutoland side; at any rate there are agglomerates and lava-flows, which would lead one to infer the near presence of a volcano, and with this re-appearance of volcanic activity one gets the Cave Sandstone coming in again. Under the eastern peak on Zureka the Cave Sandstone contains volcanic ejectamenta such as small fragments of amygdaloid lavas and melaphyre. The Red Beds are very confusedly developed in this area, that is, between Ramkakala and Zureka. The red clay is very conspicuous, and there are many thin bands of white to buish-grey sandstone; sometimes there are beds of brown sandstone with quartz crystals forming a sufficient percentage to make the rock glitter brilliantly. On the eastern part of Zureka there are pink sandstones in among the darker clays like those which Dunn describe in the Stormberg. On Ramkakala there is a basin under the mountains cut across on the south by a large east and west dyke. The whole of the farm practically is in Red Beds. Here for the first time going westwards one encounters the true Red Beds sandstone, which forms a massive white krantz that runs round the sides of the basin, forming an impassible barrier; the only way of getting at this farm from below is by means of a path round the side of a dolerite dyke. The sandstone is here 50 to 60 feet thick, and below it there are caves of considerable extent. On the west side of Ramkakala under Rankakata's Nek there are two lenticular patches of Cave Sandstone between the Red Beds and the amygdaloid.

From Rankakata's Nek there is a great spur of hills running south; most of it covered with white chalk-like sandstone, which is very like the Cave Sandstone. It occurs in immense slabs and caps, and is only to be distinguished from the upper series by a more gritty nature and by its being more bedded and alternating with red or blue clays. Higher up under the mountains the unmistakeable Cave Sandstone is encountered, and the white chalk-like sandstone on the spur must be relegated to the Red Beds. On Woodlands there is an east and west trough or rift-fault letting down a narrow strip of Cave Sandstone into the Red Beds; this strip of massive sandstone has weathered at one place into an enormous monolith which forms a conspicuous object at the head of the kloof. This spur is continued as far as Kroon Hoek and Lange Punt, and separates the head-waters of the Little Umzimvubu from the tributaries of the Kenigha. Where the Red Beds sandstone has been removed on the ridge, the underlying red clays weather to a rich chocolate soil, which is covered with native mealie lands, showing that the soil on the Red Beds is far more fertile than that on the Molteno Beds below.

Westwards of Woodlands, the Red Beds form merely a transition between the Molteno Beds and the Cave Sandstone; the last contains here a great deal of blue and red shale, and sandy clay, so that it is not easy to distinguish the Red Beds as separate from the Molteno Beds, and it is not till one comes to Deer Park that the Red Beds become again a distinct series. The Cave Sandstone is very strongly developed here, and coincidently there are volcanic necks in large numbers. On the west of Eyrie the Cave Sandstone forms a high plateau under the final slopes of the Drakensberg, and is cut into the most fantastic shapes where it faces a lower level. Near Eyrie volcano there is a small dyke of dolerite traversing the rock in a north-west direction, and along the side of the dyke there is a row of six monoliths of Cave Sandstone resembling a set of gigantic pepper-pots. The rock frequently assumes this form, as for instance on the N'Quatsha's Nek road, where several series of these monoliths can be seen. In the Cave Sandstone on Eyrie there are two caps of dolerite which form two conical hills. Behind these there there are signs of folding and crushing in the

Cave Sandstone. These can be particularly well seen on going a short way down the creek that heads near the Basutoland gate at N'Quatsha's Nek, and though one can see beds standing vertically, and sweeping synclines that should throw down great masses of Cave Sandstone to the level of the Molteno Beds, there is no evidence of any disturbance having taken place outside the Cave Sandstone. The folding also, when one comes to examine it carefully, is inconsequent; a sharp fold, for instance, with vertical limbs is seen running diagonally across the axis of a gentle syncline which shows no effects of the cross-folding. I believe the appearances now seen are not due to earth movements, but may be explained by disturbances of the sediment soon after deposition by strong currents or earthquakes. Along the N'Quatsha's Nek road there are a number of caves in the sandstone, some of them with characteristic Bushman paintings. At one of these, on the farm Bramwell, there is a remarkable collection of all the hard rocks to be found in the neighbourhood, gathered to make arrow heads by the Bushmen; they mostly come from the amygdules in the lavas or from rocks porcellanised by them. At this place also there are a few agates formed in cavities in the sandstone itself, which, though common in trachyte tuffs, are unknown from true sandstones

There are two N'Quatsha's Neks, both on Cave Sandstone and formed by the removal of the amygdaloid from the crest of the mountains. The western nek has some very remarkably shaped rocks at the top, one immense square block crowns the nek, and on the north side there is an equally curious mushroom-shaped block.

To the east of the nek, on the south side, a very good section is shown (see p. 26) in which some hundred feet of the usually soft white sandstone is replaced by Red Clay. The same thing happens on the ridge between Deer Park and Glen Alfred, where there is an outstanding little kopje on the Cave Sandstone plateau crowned by dark red clay or clay-sandstone, parts of which are spotted with green; below is a softer, light blue material. I searched this place carefully for organic remains, but found no trace of them.

At Makomereng the hill-slopes become very steep and the water channels correspondingly deep and narrow, almost cañon like. The Cave Sandstone is cut into long narrow strips, and presents a very remarkable appearance, being brilliantly white and in solid unbedded krantzes 100 to 300 feet thick, capped with dark amygdaloid.

On Tramore, Glen Alfred and Makomereng there are three isolated hills capped with the Red Beds sandstone forming the ends of ridges that come south from the mountains. On Retreat the red clay beneath the sandstone is fossiliferous, as mentioned above. On the south side of the Kenigha River there is a long ridge coming south-east from the high mountain peak called the Twins; it is capped for the most part with the Red Beds sandstone, and beneath, the red clay with purple and blue bands is well developed, both on the north and south sides of the ridge. The ridge is covered with mealie lands, so that the Red Beds must disintegrate into better soil than the Molteno Beds. (See Analysis, No. III., p. 29). South of Retreat there are three volcanoes, and round them there is a large development of typical Cave Sandstone.

Beyond the Twins, in George Moshesh's Country, there is a great horizontal development of the Cave Sandstone and Red Beds, spurs made of these rocks stretch out far away from the mountains. This is due to two causes, firstly, the level of the Red Beds and Cave Sandstone is lower in the west than in the east, that is to say, there is a slight dip to the west, and also, the level of the plain rises. At the Trappist's Mission Station, Mariazell, the Cave Sandstone is nearly on a level with the river Jordan, and to the north of the Mission House there are some splendid columns of rock, 80 to 100 feet high, and about 20 feet in diameter.

Round the York volcano there are again exposures of Cave Sandstone, one great overhanging ledge 60 feet high runs back up the narrow kloof on the east side. Further up the kloof the usual white chalky rock gives place to a series of sandstones and shales similar in character to the Molteno Beds, but over the other side of the ridge, in the first river in the Mount Fletcher Division, the rocks show one united mass of Cave Sandstone again.

Close to York House there are two or three little beds of Cave Sandstone caught up in the amygdaloid, or perhaps deposited contemporaneously with it. Along the road, also, there is a patch of beds that should normally belong to the Cave Sandstone, but which are very peculiar. The section exposed along the road, going upwards, is as follows:—

4. White chalk-like sandstone.
3. Agglomerate, hard bedded rock.
2. White and brown, fine-grained, compact sandstone.
1. White chalk-like sandstone, which gives place higher up to blue sandy clays, with hard nodules, septaria with calcite, and balls with brown earthy centres.

No. 2 has at one place a thin-bedded flaggy character, the lowermost bed shows the rounded cross rippling that is frequently seen in the Bokkeveld Beds, and which has the appearance of rolls of soft putty laid zig-zag on a flat surface and allowed to settle down ; at other places, again, there is a thin layer of sandstone a quarter inch thick, which can be stripped off the beds above ; this shows curious dragging marks, as if some floating material had been driven along, and had just touched the bottom, so that it scraped the surface of the mud ; afterwards the fine sand deposited upon it took the impress of these marks.

Further up the cutting there are some good examples of flat-topped dykes of dolerite ; they occur in the blue clay which has turned to a hard rock near the contact. The white sandstone in one particular instance has stopped the up-flow of the dyke, but has been bent upwards by it ; this indicates that the dolerite must have exerted considerable pressure upwards. The dolerite is much decomposed, and weathers spheroidally.

To the south of the Mabele River it would be hard to say whether the rocks on the ridge separating the valley from the Mount Fletcher Division belonged to the Cave Sandstone or Red Beds. There is a barbed wire fence running along the top of the ridge, to separate the Matatiele from Mount Fletcher Division, and the gate on Hilda Heath is between two hills made of white chalk-like sandstone that would be taken by most for Cave Sandstone. Further along, however, on the same level, especially on the Moiketse Location, there are red clays that one would be inclined to ascribe to the Red Beds. At Bessdale or Bertievale the rocks of the Molteno stage come up to the top of the ridge.

THE VOLCANOES OF MATATIELE.

Lying on the above described sedimentary rocks there is a series of lava-flows that form the crest of the Drakensberg range. These lavas have been traced to a number of vents which occur in the Matatiele Division south of the mountains. Most of these are rounded pipes now filled in with agglomerate or dolerite, but one form is dyke-like, and though there is some doubt as to its exact nature, there is very good reason to believe that it was an actual fissure of eruption. Short petrographical descriptions of the rocks will be found at the end.

The following is a list of the volcanoes from east to west :—

On Eyrie: one volcano, No. 1.
On N'Quatsha: two volcanoes, Nos. 2, 3.
On Deer Park: three volcanoes, Nos. 4, 5, 6.
On Glen Alfred: three small volcanoes, Nos. 7, 8, and 9.
In Tsita Moshesh's Country: three volcanoes, Nos. 10, 11, and 12.
In George Moshesh's Country: six volcanoes, Nos. 13, 14, 15, 16, 17, 18.
On York: one volcano, No. 19.

There may be some that I missed, but these cannot be very many. Three or four doubtful ones I have not counted, but the rest are well established.

No. 1.—This volcano occurs on the east of the main river that flows through the farm Eyrie. It is a funnel-shaped mass of white tuff and dolerite, of which the western half is eroded away. The valley is very steep and narrow, the height from the top of the ridge to the river-bed being about 300 feet. The actual bed of the river is in the Red Beds, and on the east bank there are blue clays and sandstones, the latter, when exposed on the hill-sides are white, but here, being unweathered, are also blue. Above the ordinary sedimentary beds on the east side of the ravine come white tuffs, with pellets of pink, blue, and yellow clay. The tuff, as is so commonly the case with the material filling these Matatiele pipes, is largely composed of quartz grains. To prove that this is really a volcanic pipe, we have the fact that the tuff occupies a vertical space in the horizontally bedded rocks, and contains angular fragments, and is traversed by dykes of lava. Higher up the kloof side on the east, the pipe is filled with dolerite, and on the top there are two beds of amygdaloid dipping in towards the centre of the pipe at an angle of 20° and separated by a layer of white sandstone like the Cave Sandstone, which is partly fused to a hard grey quartzite; on the west of the kloof there are two thick caps of dolerite which may be remnants of the flow of dolerite that came from the pipe, and of which there is still a quantity in the vent.

No. 2.—Is very similar to No. 1. It occurs north of the fork of the main stream on the farm N'Quatsha.

The sides of the kloof are very steep, and there is a good section showing the vertical pipe traversing the horizontal beds. The tuff is a perfect store-house of varieties of rock of the dolerite type, crystalline or glassy, compact or vesicular. There is a number of large masses of red clay in the white tuff, sometimes showing regular bedding, inclined at moderate angles to the horizontal. Such large blocks cannot have been ejected and fallen back into the vent, but indicate rather that the wall of the pipe collapsed.* In the north-west and north-east there are large caps of dolerite which may have come up from the vent or may be still parts of the flow from No. 1. There is no great mass of dolerite in No. 2, only ledges and dykes of that rock appear through the agglomerate.

No. 3.—Is entirely an agglomerate neck. It occurs at the head of the valley in which the Belfort shop is situated. The old road used to pass over it, but the present one goes a little way to the west of it. The agglomerate is dark purple in colour with a great number of blue and pink clay-pellets in it. The larger inclusions are mostly rounded lumps of amygdaloid or diabase, but a certain proportion are of sedimentary origin, and include limestone, which is not known in the surface rocks, of the district. The rock round the vent is Cave Sandstone, and the dark agglomerate, thickly packed with dark coloured boulders, forms a striking contrast to the horizontal, brilliantly white sandstones.

No. 4.—Is situated to the west of the western nek of N'Quatsha. It is the only one that occurs in the line of the mountain crests in the Matatiele district. It is a very conspicuous object from afar, owing to the Liberty-cap shaped mass of dolerite that crowns the hill. The dolerite forms a central plug to the volcano, and very nearly fills the cavity, only a little agglomerate occurring on the north side. The dolerite is columnar, but the columns are all split transversely into wedge-shaped segments, with curved sides. Sir A. Geikie describes a similar occurrence at Largo Law, in Fifeshire, as like "peats stacked for drying."† The columns converge slightly upwards, or normal to the base they rest upon, which must, therefore, be funnel-shaped. Round the rim of the dolerite, except on the north side, there are great blocks of Cave Sandstone, forming a broken ring. The inside of the ring of the sandstone is carved into grooves as if a great gouge had been forced up the chimney of the volcano; I was not able to satisfy myself whether these had been produced by the up-rushing material or whether they were only peculiarities of weathering.

The rim of sandstone is breached on the north side, and there are flows of lava connecting the pipe with the amygdaloids of the crest of the mountains, but owing to the exposed position of the hill, with the consequent deep weathering of the rocks, and to the grass also that covers everything, the lava flow is much hidden, but enough is shown to enable one to make out that the lava of the Drakensberg did come out of this pipe.

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* A most interesting parallel case is that of the volcanic neck of Newark Dove-cot, St. Monan's, given in Sir A. Geikie's recently published "Geology of Eastern Fife," Mem. Geol. Survey of Scotland, 1902, p. 236. The neck is 60 yards in length by 37 in breadth, and is filled in with an agglomerate of shale, limestone, ironstone and sandstone imbedded in a greenish tuff. Large blocks of strata, with all their component layers still adhering to one another, may be seen in the agglomerate, one mass measuring 24 yards by 7 yards.

† Mem. Geol. Survey of Scotland, 1902, p. 260.

Half-way between the peak and the Drakensberg crest there is a pile of lavas very well exposed. The flows represented there average two feet in thickness, and many of the intercalated flows are much less. They are all highly vesicular, and the lower part of them is occupied by the peculiar pipe-vesicles now filled in with calcite, various zeolites, or chalcedony, and opal. The flows occur in regular series, with thin lenticles in between two consecutive ones. The second flow is in part weathered off the first, leaving the surface of the latter exposed on a shelf about three feet wide and four or five yards long. The surface shows the unmistakable ropy surface which is found on lava streams when they flow slowly. The largest ropes are an inch and a half in diameter, and all sizes downwards can be found. The surface of the rope is usually smooth, sometimes ribbed, but shows no scoriaceous coating; the ropes curve and twist about, but the general direction on the surface exposed is N.N.W., and pointing directly away from the vent. The rock composing the flows is the ordinary melaphyre more or less vesicular; the ropes consist of the same material, but with very few amygdules, and these are filled in with a dark greenish mineral.

Quite different is the crystalline dolerite of the main plug. This rock was not seen in the Drakensberg in the neighbourhood, but to the south-east there is a ridge of hills capped with columnar dolerite of the same type as that of the plug. The dolerite lies a little lower than the level of the volcanoes, and it is probable that the dolerite here was poured out from the vent and formed a large flow to the south-east. If this is the case, as the plug must have been the last outburst from the volcano, and as the dolerite lies on sedimentary beds and therefore belongs to the earliest stages of the volcanic activity in the district, the whole volcano must have had a short life, and after commencing among the earliest, got buried up in the lavas poured over it from the neighbouring volcanoes. The dolerite on the hills lies from two to three miles distant from the vent, and is in places 200 feet thick. It will be seen, however, in the petrological part which follows, that all the volcanic lavas are so similar in nature that no safe argument can be based on the apparent resemblance of two rocks separated by any considerable interval.

Nos. 5, 6, 7, 8, 9, form with No. 4 a line inclined about 60° to the general trend of the volcanoes.

No. 5.—Is a very large pipe, traversed by the western stream of Deer Park a little above where it joins the eastern stream. It is about 400 yards across, but the limits, except on the north side, are uncertain owing to the amount of débris. On the north side the stream has cut its bed between the agglomerate neck and the Molteno Sandstone, leaving the former to stand up as a cylinder. The sandstone dips in towards the pipe, as if the material, in falling back, had dragged the sides of the chimney with it. The same thing is seen on the east, where the road crosses from the agglomerate to the sandstone, and the sloping surface of the latter forms an inclined plane which carts have to negotiate in getting from one side of the farm to the other. The western side of the pipe is covered with dolerite debris, so that apparently there is a small dyke in this part. The matrix of the agglomerate is white sand, and the inclusions are very largely made up of fragments of sandstones; vesicular lavas and dolerites are also present. On the outer edge of the pipe the boulders are very large, many running to over three feet in diameter; these are well seen at the drift and by the small bathing pool a little higher up. In the centre the inclusions are quite small, only an inch or two in diameter. The inclusions may be completely rounded, sub-angular, or quite angular. Among the fragments in the centre of the neck there are some small bits of charcoal, which at first sight seems to be an extraordinary thing to find in a volcanic pipe, but a quite possible explanation can be got if one supposes that there had been a period of rest before the final outburst, and that trees not only covered the hill-slopes, but also grew in the crater itself; then, when the volcano started playing, these got torn off by the uprush of ashes, and bits of them fell back with the ejected material into the pipe.

Nos. 6 and 7.—Occur in the ridge on the west of the valley in which No. 5 is. They are very much smaller than the ones hitherto mentioned, being only some 15 to 20 yards across, and might be called spiracles rather than volcanoes. The pipes are filled with white and blue tuff, with rounded or angular fragments of sandstone, red and blue clay, and igneous rocks; in both there is also a dyke of dolerite.

Nos. 8 and 9.—Are still smaller than the last, being, in fact, mere spiracles, only 6 and 4 yards across. They occur on the same ridge, and are filled up with green sand, and with fragments of dolerite, diabase, and amygdaloidal rocks, with bits of sandstone. A large portion of the vents is filled with a hard flinty rock, green on fracture when fresh, but weathering into a whity brown coat like an ordinary sandstone. It has peculiar hollows in it, and the bedding runs in curved lines like the flow-structure in rhyolites: the rock is a tuff silicified. They are each penetrated by a coarse dolerite dyke, and there is also a semi-circular dyke of this latter material beyond No. 9, on the same ridge, which marks the southern limit of the eruptive activity along this line. The next group of three vents in Tsita Moshesh's country, however, lies practically on a continuation of this line.

Nos. 10, 11, and 12.—Are surrounded by Cave Sandstone which occurs in an isolated mass on the hills south of the Kenigha River, and opposite the shop on Retreat (Makomereng). Nos. 10 and 11 occur in the face of the cliff overlooking the valley of the Kenigha. There is a prosperous Basuto village just below them, and the pathway up the hill-side goes across them. They are very noticeable, as the Cave Sandstone is, as usual, chalky white, and in this there are the bright red patches derived from the weathering of the agglomerate. The latter is very much decomposed, and consists of a yellow gravel with pebbles of dolerite, sandstone and shale. In places it is a hard greenish siliceous rock. These two are comparatively small, the eastern one being about 20 yards across, and the western half as large. On going on the top of the hill one comes to a deep valley flowing south, with a small but persistent dyke of dolerite running across from east to west, and dipping south at a high angle. The stream is only a small one, but the ground about it is very marshy, and holes 15 to 20 feet deep occur unexpectedly along its course; it is these holes that supply the eels that are caught in the district. A short way down there is a tributary that comes in from the east, and at the junction of it with the main stream there is a large pipe of agglomerate about 40 yards across. It consists of a hard green silicified tuff with volcanic and sedimentary rocks embedded in it, from small fragments up to boulders two feet in diameter; the larger boulders occur round the edge of the neck, as is usually the case when the arrangement can be seen at all. There is no lava-flow of any kind associated now with any of these necks.

No. 13.—Is a large cylindrical mass of dolerite on the west side of the ridge separating George Moshesh's country from N'Kau's. It is very conspicuous from the road that passes over the River Ribani here, leading from George Moshesh's village to the Trappists Mission Station and the shop. There is a very little amygdaloid on the north side, and the sides of the chimney are contorted and brecciated, but the rest of the block is solid dolerite. There are no flows connected with it.

No. 14.—Is the most conspicuous of all the volcanoes in the district, as it is connected with a thick flow of dolerite which has protected the vent and allowed it to remain perched up on the crest of the ridge while all the surrounding rocks have been weathered away. It is well seen from Intwantsu (or Mtohoantso) on the Matatiele-Ongeluk's Nek road. The vent is surrounded by Cave Sandstone, the outcrop of which is prolonged southward to encircle it, so that we now see the vent exactly in the position it occupied when it first started pouring out its lavas and ashes over the white sandstones. The section exposed on the surface now is funnel-shaped, the western portion being composed of hard blue agglomerate with the usual assortment of basic igneous inclusions. This is penetrated by a peculiar rock, probably a very much altered vesicular basalt, now consisting of a mottled mass of green and white earthy minerals. The eastern portion of the pipe is occupied by columnar dolerite, the columns, as in No. 4, converging upwards; the flow of dolerite, however, that laps over the rim of the funnel is not columnar.

No. 15.—Is a great plug of dolerite and amygdaloid about ⅓ of a mile in diameter; it is cut round on three sides by the River M'Rumisso and one of its tributaries. There is near here a great sheet of dolerite that comes up from under the Cave Sandstone at a sharp angle, and the eastern outcrop of which runs north and south, but there is no apparent connection of this dolerite plug with the sheet; it should be noted, however, that the same relation of sheet to plug occurs at the York volcano, No. 19, and it is at least probable that these two volcanoes started to work and poured out lava before the end of the deposition of the Cave Sandstone, and that consequently they were either subaqueous, or situated on a shore which was rising and falling. The sheet might have been either intrusive or previous to the deposition of the Cave Sandstone; from the appearance in the field I am inclined to the latter view, in which case the dolerite plug, being subsequent to the deposition of the Cave Sandstone, must either have been quite independant or have resumed work after a considerable period of quiescence. The flows from this vent are probably to be found all round in the amygdaloidal lavas, and the volcano being one of those that kept in working order to the last, the flow of dolerite, of which the plug is part, would be found at the top of the series of lavas.

No. 16.—Is very badly exposed. It occurs just outside the edge of the great lava sheet mentioned above, and is encountered as one passes down the steep ridge towards the last volcano, No. 15. It is purely agglomerate, a hard blue siliceous rock, with the usual assortment of coarse and fine material, boulders of dolerite and amygdaloid, pink and blue clay, etc.

No. 17.—Is a small plug of dolerite occuring on the ridge behind Jeremiah Moshesh's stadt.

No. 18.—Is a pipe of agglomerate magnificently exposed on the steep sides of the ridges overlooking the Mabele Valley and the red decomposition products that strew the hill-side make it a conspicuous object from afar. A small rivulet cuts back right into the pipe and exposes vertical sections of the agglomerate. The rock exposed is really the eastern wall of coarse material, the softer centre being washed away; the boulders are mostly of large size, and include the usual varieties of basic rocks, with a certain proportion of shales and sandstones. The assortment of boulders in a dark blue matrix reminded one strongly of some varieties of Dwyka Conglomerate. To the north-west there is a moderately thick sheet of dolerite that might very well have flowed from this neck, but there is no dolerite now in the chimney, so that, if the two are connected, we must suppose that after the first dolerite overflow, the volcano had a long life, finishing up with an explosive stage, which cleared out all molten rock from the vent. This, however, is an inversion of the accepted order in which the agglomerate and lava flows are supposed to be related, the former being usually taken to be formed previously to the latter. In the case of the next volcano, it will be seen that there is additional evidence for the sequence I have postulated above.

No. 19.—Is the largest volcano in Matatiele; there is both an enormous neck of agglomerate and decomposed amygdaloid about a mile in diameter, and also on the west side a plug of dolerite, very little less in width, with a great overflow of dolerite to the east and south. The agglomerate is exposed both by a small tributary of the Mabele, dividing the neck in two, and by the new road that is cut for some way through it. In this way very good sections are exhibited. The rock is a dark blue tuff, with a great variety of basic, igneous, and sedimentary rocks in it. Up the slope to the west decomposed lavas occur, now converted into a green mass, with grey patches and riddled with white zeolites. In the section along the road there is shown a dyke of dolerite, penetrating the agglomerate and passing horizontally into a sheet.

The dolerite plug is connected with a heavy flow of columnar dolerite, that spreads out for about a square mile to the south and east of the vent, and further away to the east thinner caps occur on the top of the hills, and still further, on Moiketse Location and Manning, there are again very thick sheets of dolerite that may possibly belong to this flow. The small tributary that divides the agglomerate neck in two has also cut through the dolerite sheet, and has exposed the junction of it with the Cave Sandstone. The latter rock forms immense solid krantzes, that give the narrow kloof a very remarkable appearance, so weird in fact that my boys were too frightened to go up the kloof to gather firewood, though this was the only place in the neighbourhood where it could be got in reasonable abundance. C the west of the kloof the Cave Sandstone is capped with amygdaloid, and it is only on the east that the palisade of the dolerite columns is shown.

The area round, for an extent of about four square miles, shows very plainly a dip towards the vent, whether due to the loading of the strata at this particular point with an enormous pile of lavas, or whether to a local sinking of the crust, because of the rock beneath being carried away and thrust out at the surface, is not apparent; probably both factors entered into the production of the dip. Most of the lavas round the neighbourhood, including the enormous masses exposed from here up to the top of Ongeluk's Nek, probably came out of this hole; the great mass of decomposed amygdaloid in the pipe, though now quite different through decomposition from the pipe amygdaloids of the flows, was evidently of exactly the same composition in the original condition. The dolerite sheet above referred to was among the first of the flows; then followed the more vesicular lavas, to the west and north. Some of these must have been poured out before all the Cave Sandstone had been deposited, because the latter lies on the amygdaloid between Hilda Heath and York. To the west of the vent, also, the same thing occurs, but here there are also bedded agglomerates lying in the Cave Sandstone, showing that the volcano at that period shot out its ashes and lapilli far and wide. It is very remarkable that this tuff or bedded agglomerate is not found more widely; the beds that one finds between the lava streams are not of that nature, but are ordinary red clays or white sandstones, baked and hardened in places, but never composed of volcanic ejactamenta.

The rock that came from this volcano, except for the dolerite flow already described, which was an initial effort, was mostly amygdaloid. The Ongeluk's Nek section exposes 4,000 feet of it, and only occasionally is there a bed of more compact rock or true dolerite. Near the vent itself there are several more or less large patches of sedimentary rocks included in the lava; these are probably deposits formed during temporary subsidence of the land surface beneath the sea, since the sediments are not of a nature that would accumulate in a shallow lake formed on the flanks of a volcano, since they are much too siliceous. Besides these, however, there are deposits that may have been formed in small lakes or along the courses of the water runnels on the sides of the volcano itself. Some of these are now converted almost into porcellanite by the baking they have received from the lava. It is interesting to notice that the sides of the porcellanised rock are the least altered, a fact which may be due to the molten lava being suddenly cooled at the contact with the damp mud, and forming a non-conductive layer on top of it. This would prevent the mud being scorched at the surface, but then afterwards, when the enormous heat of the lava began to diffuse itself through the rocks below, the included sediments became baked in the way they are. The porcellanised rock had been taken for gold-quartz by the diggers, in the rush of a few years back, and had been sunk upon in two places. Some of the lava streams are parted by an earthy and gritty brown material, which may be the actual soil that formed on the mountain slopes.

That there were long periods of rest in the history of the volcano, during which the surface became carved into by the erosive forces of wind and weather, is shown by some of the lava streams exposed on the opposite side of the Mabele River, above the old prospecting works. Here there are shown gulches filled in with lava; an especially fine one shows the wide sloping valley, with a narrow channel at the bottom. The channel was cut in amygdaloid, and is filled in with the same material. The rock weathers spheroidally, but at the contact the following section occurs:—

Compact stony layer...	.5 inch.
Lava, finely vesicular	1.0 inch.
Compact stony layer	.5 inch.
Pipe amygdaloid	4.0 inches.
Amygdaloid	—

It is interesting to notice that the pipe amygdules always stand normal to the surface, even when this is highly inclined, a fact for which I can offer no explanation, as one would think that gas in expanding would always tend to force its way vertically upwards. Cohen[*] believes that there was no flowing motion after the vesicles had formed, and explains their length and branching by supposing that at the time of their formation the rock was very fluid, thus allowing the vesicles to expand vertically upwards, but this will not help to explain how a whole row of vesicles became inclined normally to the steep side of a gulch, down which the lava must have flowed. In this particular case the old gulch leads north, whereas the amygdules are inclined to the east and west.

There are two or three places which are very peculiar, and I was long in doubt as to whether there might not have been some volcanic outburst at them. The first is in the amygdaloid on Motley's Hoek, and occurs near the top of the ridge on the south bank of the river Jordan. It is a large circular space, occupied by dolerite, whereas the surrounding rock is amygdaloid. It is on the line of one of the three dykes that come through from the Mabele Valley. There are some very large hollows in the rock about here, mostly filled in with quartz and calcite, sometimes with carbonate of iron as well. In this case the dolerite of the plug, if the place be volcanic, weathers so like the surrounding basic amygdaloids that it is quite impossible to arrive at any definite conclusion from the examination of the rocks on the surface, and I have therefore not counted this occurrence as one of the volcanoes of Griqualand East.

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[*] Neues Jahrbuch, 1875, p. 113.

The second occurs in a dolerite flow on George Moshesh's ground, on the ridge to the right of the westernmost stream that comes down from the crest of the Drakensberg. There are two little crater-form hillocks, which, seen from a distance, look exactly like two small volcanoes. They lie on the same line as the last-described occurrence, and the long cross-country dyke that comes from the Mabele Valley. They both have springs rising in them, and the better preserved of the two holds a small dam. The present hollow in the crater might be due to the springs which soften and decompose the rock in their neighbourhood, but what has given the rims the harder texture, enabling them to stand out from the rest of the dolerite, I cannot conceive, unless it be that these were small volcanic vents.

The third doubtful case is on the east of the district, on Zureka. Where the valley heads under the eastern beacon of Zureka, there is a large, rounded, funnel-shaped hollow, mostly covered with blocks of amygdaloid that have fallen down from the crest of the range. The Basutoland fence runs along the watershed, and prevented me from effectually examining the north side of the range, which might have thrown more light on the geology of this spot. Part of the watershed is in Cave Sandstone, which here has in places many included bits of igneous rocks, like a tuff.

On the west side of the hollow there is a large isolated flow of dolerite, and between this and the fence there are several very peculiar rocks, among which are dark green, glassy rocks, with a surface weathering in a network of pink veins, and a light green mass, probably the decomposition product of some igneous rock.* Below these, and intruded in between the Red Beds and Molteno Beds, there are sheets of dolerite, as mentioned above, which look as if they might emanate from some centres of eruption in the neighbourhood, and the Cave Sandstone also comes in here in its normal thickness, after being absent for a long distance from the west. I am inclined, however, to think that the curious rounded hollow is not the pipe of the volcano, but merely due to denudation, and that we must look over the other side of the Drakensberg, in Basutoland, to find the true vent.

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* See the descriptions in the petrographical part, slides Nos. 961 and 963.

FISSURES OF ERUPTION.

Between Deer Park and George Moshesh's Country there is a dyke of dolerite running under the mountains, and parallel to their crest, having a general strike of E. 25° N., but bending due east at Makomereng to follow the changed direction of the crest. It cuts mostly through the amygdaloids, but in the middle basin in Maklagala's country it leaves the amygdaloid and traverses a tract of Cave Sandstone. On the east of Maklagala's country it broadens out to about a mile in width, but elsewhere it is only a dyke about twenty yards thick. The rock weathers more readily than the amygdaloid, owing to the spheroidal cracks that are set up in it when it is near the surface, whereas the amygdaloid flows present a solid mass to the destructive agencies of wind and water. For this reason there is a longitudinal depression running high up under the mountain crest, and this is used by the cattle to get from spur to spur of the range.

It is not easy to make out the course of the dyke in some places, as the weathered products of the amygdaloid and dolerite are so similar, but the presence of the dyke can generally be detected by great yellow scars on the hill-side, due to the dolerite breaking down to a yellow crystalline sand. On Makomereng, however, where the dyke runs close up under the crest of the mountains, the streams have cut narrow kloofs through the igneous rocks; so steep are the sides of these that débris is unable to lie, and clean sections are available for study. Here one sees the dyke traversing the regular bedded flows of lava, and in some cases on the south side the latter are up-turned. At a certain level the dolerite forms a conical heap, the edges of which spread out into horizontal sheets lying on the amygdaloid and again covered by that rock. There were no data that I could find which could prove that these heaps and sheets of dolerite were not intrusive in the bedded amygdaloids, but were contemporaneous with them. If there had been the rending and bursting of the overlying amygdaloid with dykes of dolerite, that rock naturally would have been intrusive; or if there had been a zone of scoriaceous rock in the dolerite, it, on the other hand, would have been undoubtedly contemporaneous: but with the absence of such data as these, one has to rely on the general appearance of the section, and this was certainly in favour of the dolerite having been poured out on the surface, and then buried up again by amygdaloidal lavas.

A short way to the west of the Makomereng boundary the same dyke shows very strongly developed spheroidal weathering, the kernels of the spheroids being fresh rock, with the outer shells weathered to a sandy condition. On the north side, the amygdaloid is much disturbed and crushed; parallel to the vertical face of the dyke there are innumerable small cracks in the amygdaloid, which have been filled in with zeolites, giving the rock the appearance of a sandstone with vertical bedding planes. The amygdaloid above the dyke is full of large pipe-amygdules in two or three rows. The great alteration of the north wall of the dyke points to the conclusion that the dolerite must have risen explosively in the crack, and did not get gently thrust in a crack already formed for it, as seems to have happened in all the other cases in the district, with the one exception of the dyke south of the shop on Retreat, where again we suspect that the dyke was a fissure of eruption.

The main body of the dolerite is in the eastern basin in Maklagala's country. Here it is bounded on the south by Cave Sandstone, and on the north by the amygdaloid. The rock is very uniform in character throughout, being a moderately coarse-grained dolerite; occasionally very fine-grained rock and veins of glass occur, and in one or two places a variety that appears to have been a semi-glassy rock, a variolite with spherulites about the size of a marble, but I was unable to get any specimen that was not completely rotten.

It is quite possible that some of the lavas of the Drakensberg came from this fissure, but there is no section showing a connection of the dolerite with the piled lava-flows near the main body of the former. This is what was to be expected if the dyke was a fissure of eruption, for the dolerite in the crack would be the last effort of the volcanic activity, and all the rock previously poured out would be cut through and detached from this last plug. Certainly, however, it seems improbable that such an immense body of molten rock could come so near the surface without pouring over. It should be noticed, also, that in the neighbourhood of the main mass of dolerite there are no volcanic vents, it is as though the upward strain had to be relieved here by the fissure.

From Rankakata's Nek there is a very peculiar dyke running due east, and forming the boundary between Ramkakala on the one side, and Joe's Luck and Robert's Vale on the other, and running half-way through Mount Fred. It is highly inclined to the south near the nek, but further away it becomes vertical. The dyke is very massive, and consists of coarse-grained dolerite, with a central band of some variety that weathers more rapidly, yet which in the fresh state is indistinguishable from the rest. The thickness of the whole is about four hundred yards. It forms an effectual screen, separating the valley of Ramkakala from the country to the south, and is weathered into a number of sharp-pointed, conical hills. The most remarkable fact, however, about this dyke is that in the middle, that is, along the stream that comes down from the mountains near the house on Robert's Vale, there is a gap in the dolerite, and the sandstone beds pass quite undisturbed and horizontally from side to side of the great dyke. On the north side there were very good exposures of the contact of the igneous rocks with the Red Beds, which are unaltered, but on the south side, on Joe's Luck, one notes a good deal of porcellanisation and baking of the shales in the neighbourhood of the dolerite. The dyke mentioned on p. 28 may also be one of these fissures of the eruption.

It may be well here to briefly sum up the results of the examination of these volcanic necks, and to compare them with others known to exist in other parts of the world. The study of the recent eruptions in the West Indies will, no doubt, help to elucidate some of the obscure points in the structure of the South African ones, but so far, the full reports of the scientific expeditions sent to investigate the former have not been published, or have not yet reached South Africa. It was during the discovery of this new volcanic area in Matatiele that the outbursts occurred in the West Indies, and the efforts of the Geological Survey were not appreciated in the district, as it was thought that the volcanoes might prove sympathetic, and start work again. The sharp earthquake shocks that are by no means infrequent in this part of South Africa gave some sort of reason to the fears of the people, but the orifices of the volcanoes have been closed for such an immense period of time, even speaking geologically, that there is no possible chance of their breaking out again.

Mr. Dunn, who up to now has been our only authority on the stratigraphy of the Stormberg area, was also the first to describe these volcanic vents. In the two maps printed to accompany his report on the Stormberg Coalfields, 1878, only the Molteno section of which, however, was issued to the public, he marks five volcanic centres in the neighbourhood of Jamestown and Molteno, although he mentions only three in his report (p. 11). The present description of the nineteen newly-discovered vents in

Matatiele is only a further instalment of the work begun twenty-five years ago by Mr. Dunn; an immense tract of country will have to be surveyed before the complete history of this volcanic region is revealed.

It is impossible to doubt that in these pipes of agglomerate we have, in many cases, the actual conduits by which great masses of rock in a molten state have come from deep down in the earth to the surface, and in others, channels, reaching in like manner to great depths, by which great volumes of vapour and gases under immense pressure have cleft their way with explosive violence to the surface. The lavas that flowed from these vents cover, and in many cases include, strata that are certainly not younger than Jurassic, and in the immense lapse of time between then and now, it is evident that all surface features, such as the cones, craters, and fumaroles have long been washed away by the ordinary working of atmospheric denudation. What is left are merely the stumps and cores of the volcanoes, but by piecing together the evidence from a number of vents, and comparing it with what we know from other volcanic areas, both active and extinct, we can reconstruct with a very fair amount of accuracy the surface features and conditions that existed in the times when the volcanic force was in full activity in the Drakensberg.

One of the first facts that strikes one on considering the whole of the evidence afforded by the Matatiele vents is that they are all intimately related to some great line of structural weakness in the earth's crust in this district. The present coast line trends N.E.; the great line of laccolites from Tsolo to Mount Ayliff trends N.E.; the main watershed of the southern part of the continent from Cape Town to Delagoa Bay trends N.E.; and when we come to join up the centres of eruption in Matatiele, we find that they lie along a line trending N.E., with the exception of a small number by Deer Park, which, however, are situated also along a definite line. Further, if this principal line of volcanoes is produced to the S.W., it will cut the five vents discovered by Mr. Dunn near Molteno and Jamestown.

There is no evidence of any faulting in the neighbourhood of the vents; where one can get a clear section of the sedimentary beds across the Drakensberg, such as at NQuatsha's Nek, the rocks on either side are seen to be perfectly continuous. A line of weakness, however, need not necessarily show as a line of faulting; a fold deep in the earth's crust might produce a cleavage, which would allow the escape of the molten magina without producing any effect on the surface, and even a fault can die out vertically upwards, as is the case with many thrust-faults that one can study on the side of mountain kloofs. There are well-marked faults in the district, especially along the southern bend of the Kenigha River, and these lines of weakness are occupied sometimes by dolerite dykes; the fact that there are no vents along these faults is an evidence in favour of their being later than the volcanoes, and consequently the dolerite dykes were similarly of a later date. The evidence, however, is not conclusive, for volcanic vents are known to occur plentifully in areas that have been previously or contemporaneously faulted, without the escape of material taking advantage of the dislocation.

The great difficulty in accounting for the perforation of the crust of the earth by these pipes is the want of a known agent sufficiently powerful to accomplish it. The experiments of Crookes' have shown that gases under an enormous pressure in an iron shell take advantage of any minute cleavage or weakness in the metal, and drill for themselves perfectly straight, smooth holes, which are strictly analagous with the volcanic vents. But then, if the difficulties for the gas to escape be increased, it is perfectly within the power of a laboratory experiment to prevent the escape of the gas at all. The force required to break through the crust of the earth must be enormously greater than that required to break through an iron shell, and as the most violently expansive gases we know, under the greatest pressure we can produce, can easily be controlled within an iron shell, the question arises: are gases competent agents for accomplishing the drilling of the volcanic vents? Or are there gases of enormously greater elasticity than any known to us? Professor Daubrée* has suggested the word "diatreme" for these cylindrical chimneys, blown through the crust, as he thought is proven by his experiments of dynamite on granite, by the explosion of gases in the interior of the earth; it is, perhaps, best still to use the term pipe or chimney till further proof is afforded that the "diatremes" do originate in an explosion of gas, and even then, would not all volcanic pipes be probably due to the same cause?

The sedimentary rocks, through which the chimney is pierced in the Matatiele instances, never show the least sign of shattering or plication, the wall of the hole is clean cut, and the division between the agglomerate and sandstone quite sharp. On the high volcano on Deer Park (No. 4) there was doubtful evidence of scoring of the ejected blocks against the sides of the vent, but the great gouge-like channels on the interior of the rim of Cave Sandstone may have been caused by unequal weathering. As a rule, there is a slight dip of the strata round the hole. This is not always apparent, as the vents are so commonly now surrounded by the thick unbedded Cave Sandstone where any moderate dip would be very hard to detect; but on No. 5, in the lower valley of Deer Park, where the surrounding strata are hard sandstones of the Molteno series, the dip is very apparent. Round the York volcano, the beds for a considerable distance round dip towards the vent, but this is hardly a direct effect of the volcanic orifice, being due to the general weighting of the surface with enormous piles of lavas, coincidently with the taking away of the same material from beneath the crust. In the fissures of eruption, however, both in the great one under the Drakensberg, and the smaller one south of the shop on Makomereng, the north wall of dyke is intensely crushed and fissured, and injected with the igneous material.

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* Bull. Soc. Géol. France, 3me Sèries., tom. xix. (1891), pp. 313-354.

As already stated, it is usual to suppose that the volcano started with the drilling of the hole, and if no lava followed, the shattered materials flung up into the air tumbled down again and plugged up the vent; after that, there was no further display from that particular volcano. Such is the history of the Shetland necks*, and of the smaller Fifeshire ones, such as those east of the Rock and Spindle.† In the Matatiele vents, however, we have clear evidence in Nos. 14 and 19 of a lava flow earlier than the consolidation of the agglomerate in the pipe, and I do not see any hindrance to the acceptance of the theory that this order was generally followed in the history of the volcanoes. That is to say, instead of the explosive action being merely an abortive effect at the institution of a full-developed volcano, that that action in most cases was a final effort after the extrusion of the lavas, when the pipe became blown larger, and not only the sedimentary beds, but also the superincumbent lava, already long since hardened, became shattered, and went to form the final agglomerate. Not only is this an apparently natural deduction from observed facts in the field, but it is also supported by the knowledge that among active volcanoes a violent explosive stage may succeed a vast period of comparative quiet lava and ash discharge.

The material composing the agglomerate is derived from rocks now exposed at the surface; the matrix is, one can say with confidence, derived from the same source as the Cave Sandstone is: not only is the general appearance the same, but the same kind of felspars, including microcline, are seen in both. The blue and buff siliceous matrix is probably derived from the deeper sandstones, such as those of the Molteno Beds, blue being the universal colour of unweathered sandstones of this series. No tuffs of undoubted volcanic origin occur, the matrix is always such as is derived from the shattering of non-volcanic beds, and there are no individual crystals of minerals which one can say could have been derived from a molten magma. In most explosive volcanoes, and the West Indian ones are very typical examples, the gases seem to have blown through a molten magma, and a rain of ashes, consisting of small porphyritic crystals of felspar, ferro-magnesian minerals, such as augite and hornblende, accessory minerals, like magnetite, and bits of glass and pumice, covers the land for immense distances, and presumably would clog the vent if the action stopped at this point. In the Fifeshire volcanoes such agglomerates are found; individual crystals of orthoclase, hornblende, biotite, and pyrope garnet abound. In a similar way the agglomerate of the Kimberley diamond pipes is composed of disintegrated magma that was once molten, and isolated crystals, such as augite, biotite, garnet, and ilmenite are characteristic of the rock.

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* Peach and Horne, Trans. Roy. Soc. Edin., xxxii. (1884), p. 359.

† Sir A. Geikie, Volcanoes of Eastern Fife, Mem. Geol. Survey, Scotland, 1902, p. 213.

In many of the Matatiele vents the boulders in the vents are for the most part purely sedimentary. These all belong to the surface rocks of the district, except, as far as the examination went, in the single case of No. 3 volcano, in the agglomerate of which crystalline limestone occurs, a rock unknown in the Stormberg Series. Usually, however, there are lavas associated with the blocks of sedimentary origin. In the high volcano on Deer Park, No. 4, there are actual bombs, that is to say, portions of the magma that have been hurled into the air and cooled as they fell, for the blowholes are arranged symmetrically to the surface of the boulders, the outer rim containing minute cavities, and the centre being more coarsely vesicular. Elsewhere, however, I did not find similar bombs, the lava blocks being evidently such as had been consolidated before the date of the formation of the agglomerate, as could be seen from the disposition of the vesicles to the surface of the fragment. This last fact is an additional evidence that the agglomerate was formed late in the history of the volcano, as it is probable that in many cases the blocks originally came up as a lava flow, that became hardened round the vent, and on the final explosive stage ensuing, this flow became shattered equally with the underlying sedimentary beds. Whether bombs are in reality more frequently present can only be decided by a much longer study of the area, and in a preliminary reconnaissance like the present survey, such points cannot be settled.

Comparing the size of these necks with the Fifeshire ones, as these may be taken as a most typical example of a similar area in Europe, Sir A. Geikie gives for the latter the limits in the diameters as between ten yards and a mile (Largo Law). Nos. 8 and 9 are smaller than the smallest of the Scotch ones, being only 6 and 4 yards across; and the York volcano, No. 19, is probably larger, though the uneven nature of the present surface renders measurements only approximate, and a very careful survey alone could determine the exact size. In shape the chimneys are roughly circular, but the north and south diameter is usually the longer. In the York volcano, where a dolerite plug lies alongside an agglomerate neck, the longer axis of the whole is east and west.

That the pipes have been filled in from above is, of course, a natural conclusion, but it would be difficult to prove the fact did we not find bits of carbonised wood in the agglomerate. These fragments are undoubtedly boughs torn off from the trees that were growing in the neighbourhood of the vent, and probably in the crater itself. The same thing has been noticed in the Fifeshire volcanoes, and in the case of these I find it difficult to reconcile the idea that the agglomerate was merely the result of an initial effort of the volcanic forces at the particular spot, with the fact that these boughs in all probability grew inside the crater. Their presence indicates a period of rest after the initial outburst forming the material of the crâter, during which the trees grew to maturity, for the logs of wood are of considerable size; there must have been, at any rate, a second period of activity to account for these bits of wood having been dragged down into the chimney. In this respect, at any rate, the Matatiele volcanoes agree with the Kimberley pipes, for many large tree trunks have been unearthed from the diamondiferous blue, some fine examples of which are exhibited in the South African Museum.

It is hardly safe, from the little we yet know of the geology of the adjacent country, to speculate as to the probable extent of the whole volcanic field of the Drakensberg region. An immense lateral extent of amygdaloidal lavas is known to exist all over Basutoland from the Orange River Colony border to Natal, and it is very probable that the Matatiele volcanoes may be merely the south-eastern border of a broad band of country riddled with volcanic necks as in Central France. What is very apparent, however, from the present survey is that an enormous field of research has been opened, and one of exceptional interest; but the nature of the country is such as to render it at present extremely difficult to map, not the least of the obstacles being the intense hatred of the Basutos to inquisitive strangers who might, they think, discover minerals in their country, and bring into their preserves an alien white population who would make them work. It may, however, not be out of place here to express my sense of gratitude to the Basuto chief, George Moshesh, who has settled in the colony, and in whose country I camped for some time; on explaining the object of my survey to him I received a great deal of help from him and his tribe.

THE LAVAS OF THE DRAKENSBERG.

The LAVAS of the Drakensberg are mostly basic rocks, of the basalt or dolerite type; a description of the varieties will be given in another place, but the common type, the amygdaloidal melaphyre, calls for a short notice here. The rock was first described by Professor Cohen from specimens sent to him by Mr. J. Orpen from Basutoland. Cohen's specimens were dark decomposed rocks, with very little recognisable minerals in them, but I have obtained fresh specimens showing the minerals distinctly; the colour of the rock in the latter case is bright red. The rock varies from a compact mass to one more or less vesicular; the vesicles increase in size, and finally become elongated into branched pipes four inches long. It is this last form that is the most striking one in the Drakensberg. The vesicles are about the thickness of a lead pencil, more or less bulbous and irregular on the surface, and frequently branching like a piece of red-coral. The vesicles stand perpendicular to the surface the lava rests on, and there is always a layer of compact rock at the base of the flow, where some of the material has been chilled quickly. Often, too, there is a layer of vesicular lava and another zone of compact rock before the layer of pipe-vesicles is reached; above this layer there may be one or more irregular bands of pipe-vesicles separated again from the first by compact rock. In most cases the amygdules are filled in with calcite, chalcedony or some of the zeolites, often with an outer casing of some green material. Cohen says his specimens had heulandite in the vesicles, but I have not been able to determine the zeolites in my specimens yet, but Mr. du Toit has since made out heulandite, thomsonite, stilbite, and perhaps scolecite. The blocks of amygdaloid that occur in the agglomerates often have the vesicles empty, but in the lava-flows that is rarely the case.

Ueber einige eigenthumliche Melaphyre-Mandelsteine aus Sud-Africa, Neues Jahrbuch, 1875. Mandelstein aus den Maluti Bergen, ib. 1880.

As to the origin of these curiously shaped amygdules one must suppose that the rock as it came out at the surface held a great amount of water-vapour occluded in it, and that the eruption of the lava was so sudden that the water-vapour had not time to get expelled in any quantity on its way from the lower regions of the earth's crust. As the lava stream cooled, the upper surface became solid first, and expelled the greater part of its water-vapour; then the lower layers, cooling last, were unable to expel the water-vapour owing to the upper layers having become impervious, and thus the vesicles became formed. I do not think it is necessary to suppose a slow motion of the lava after the formation of the vesicles in order to explain the anastamosing of the neighbouring pipes, as Cohen thinks; the confluence of two hollows in a viscid mass would take place naturally owing to small convection currents set up in the cooling material. What is hard to understand, however, is how the water-vapour was able to maintain its high pressure till the upper surface of the lava became cooled, as the large spaces forced asunder by the expansion of the vapour indicates the release of a very considerable pressure. It is perhaps possible that there is a critical temperature in the molten rock above which it can hold water-vapour occluded in large quantities, but below that temperature it is no longer capable of containing the water. The question opens an interesting field for laboratory experiment. Wittich* describes from the Melaphyr of Darmstadt some large cylindrical hollows which are filled in with rock slightly different from the rest. These he ascribes to the expansion of vapour unable to escape owing to the chilling of the surface. They appear to be something of the same nature as the Drakensberg pipe-amygdules, though they are much larger, varying from 5 to 25 centimetres in diameter.

The volcanic vents in Matatiele do not exert any influence on the form of the Drakensberg range, taken as a whole. It strikes one at first as odd that the vents should all be south of the lavas they erupted, and that with only a few exceptions there should be so few lava-flows to the south, but a little consideration will easily show that this is a necessary consequence of the position of the mountain range. When these volcanoes were erupted, they formed a screen that intercepted the wind blowing in from the sea, a wet wind, and probably a southeasterly one. On the lee-side there would be very little precipitation, whereas the windward side would be kept moist;

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* Tschermak's Mitth., Bd. xxi., Heft III, p. 185, 1902.

consequently the erosion of the two sides would be very different, that facing the sea would be cut into a very much greater rate than that on the inland side. It is, therefore, very evident that in course of time the cutting back of the sea-ward side would advance up to and beyond the central-core of the volcano. This is what happened in the Drakensberg; the crest of the mountains has receded from the original position over the vents northwards and westwards owing to the greater erosion on the south-east side of the mountains than in the north-west. Basutoland on the north-west, in fact, has more the character of a plateau that has been deeply cut into by the rivers than the slopes of a great mountain chain.

The sedimentary beds all dip slightly in towards the mountains, and in the country south of the mountains this has produced certain effects that are at first somewhat puzzling. Round about the village of Matatiele, for instance, one gets hills higher than the level of the Cave Sandstone, yet without a capping of that rock; owing to the smallness of the general dip this is not noticed at first, and one is inclined to think of faulting. The dip may be due to the exhaustion of molten rock from beneath the earth's crust, or the weighting of the crust by the lava; probably both causes operated.

The Drakensberg goes under several names among the natives, the title so often seen on the maps, "Quathlamba," I never heard mentioned in the district. The Basutos call it, and the parallel range on the other side of the Orange River in Basutoland, the Malutis or Double Mountains. The highest point in the Matatiele district is the western peak overlooking Ongeluk's Nek, which rises to 9,000 feet, but from N'Quatsha's Nek there can be seen one still higher, on the opposite side of a tributary of the Orange River, which is said to be 10,000 feet high. From Ongeluk's Nek one can see on a fine day Giant's Castle in Natal, rising, with the Mont Aux Sources, to the highest elevation in South Africa, namely, 11,000 feet. The latter mountain mass is hidden by intervening ranges from Ongeluk's Nek.

To the west of Ongeluk's Nek the mountains present an unbroken wall to the south, with scarcely anything in the way of peaks or clefts, but east of the nek the mountain range becomes very strikingly picturesque. Two fine peaks in George Moshesh's Country are very noted, both split in the summit; the southernmost is called by the English the Twins, but the higher of the two component peaks is called by the Basutos Makalale. East of the Twins there are three monoliths of amygdaloid perched equidistant on the crest of the mountain, and called by the English the Three Sisters, but the Basutos call them the "Woman with Twins," Mafagha. The monolith is very frequently repeated in the amygdaloids owing to the vertical jointing that often traverses the rock; another good example is the Thumb on the great massive peak to the west of Makomereng. Pathela's peak is different from the rest, being a finely proportioned cone; on the east of it the amygdaloid is cut right down through to the Cave Sandstone at N'Quatsha's Nek, which is really a double pass, owing to there being a block of amygdaloid in the middle. From N'Quatsha's Nek to Mangalore the range is again uninteresting. Between Mangalore and the Inhlangwini Location there is a nek similar to that at N'Quatsha, being divided into two by the great block of amygdaloid on Zureka.

The Drakensberg form the water-parting between the Orange River and the south coast streams. It is now guarded by a barbed wire fence to prevent the crossing of diseased cattle from Basutoland into the Colony, and there are only a few gates which are guarded by native policemen. The gates are from the west—Ongeluk's Nek; in George Moshesh's Country, Pack-ox or Nema's Nek, and Gamgha's or Kaia's Nek (shut); in Maklagala's Country, Sarah's Nek (shut); Makomereng Nek (shut), N'Quatsha's Nek; Rankakata's Nek, Ramkakala's Nek (shut), Mount Fred (shut), and Zureka (shut). All these are pases that a man can ride up on horseback without dismounting, but N'Quatsha's Nek is the only one which a wagon can get up. Ongeluk's Nek road is being cut, but the mountain part is yet untouched. If the others are used for draught animals, sleighs are used.

When one looks at the River System of South Africa as a whole, one finds that there is a well-marked water-parting running in a straight line from the Cape Peninsula to Delagoa Bay, a distance of about 1,000 miles. This water-shed runs north-east. From either side the rivers come off regularly except in the region opposite the Drakensberg. Here the rivers show evidence of having been diverted from their natural course to the south or south-east. The waters are collected by the Orange River, which cuts across the watershed between Colesberg and Bethulie, and is the only river that cuts the natural watershed in the whole of its course. The line of volcanoes in Matatiele, adding the five found near Molteno and Jamestown by Dunn, runs parallel to the water-shed, and it is against these that the headwaters of the Orange River abut, and are thereby deflected. There is good evidence that the volcanic range was thrown across the river system as it now exists; that means that the Karroo was dry land when the eruptions took place. One must conclude, however, from the evidence afforded by the large amount of sediment that is intercalated between the lava-flows, especially to the east of N'Quatsha's Nek, that the water-level must have been above a great mass of the lavas. It is just possible that this may have been due to submergence not great enough or not of sufficient duration to allow of a disturbance of the already formed drainage of the Continent.

We have seen reason to believe, in considering the York Volcano and No. 15, that they were started near the shore, for some of the sedimentary rocks intercalated between the lavas have the appearance of having been laid down in open water. If this be so, then the Matatiele Volcanoes lay along the shore of a continent cut off in a north-easterly direction, exactly as the present shore is cut off a hundred miles away from the volcanoes. This persistence of the north-east strike of the successive shore-lines to South Africa is very remarkable. In Permian times, as far as we have seen, the shore-line ran north-east from Prieska to Mafeking, then in Jurassic times the shore-line was that on which the present Matatiele volcanoes was situated about 150 miles distant from the previous one, and the present one is 100 miles from the Jurassic one trending in the same direction.

As the deposits of the Stormberg were formed close in shore, the muds, on account of the perfect preservation of the delicate fern-leaves, and the sandstones on account of the coarseness of the grains which could not have been transported far by water; as also the Molteno sandstone is made up of crystalline quartz, felspar crystals and mica flakes with occasional garnet, that are clearly the result of the disintegration of a granite region, and as there could be no granite region near enough to afford the material except in the south, there is a very good reason to believe that there was in Jurassic and previous times a land to the south of the present coast line, and which came near it in the neighbourhood of the Transkei Territories at the end of the deposition of the Stormberg Series. This land may have extended right across to India in a north-easterly direction, and the islands Madagascar, the Seychelles, etc., that are still found above sea in this space and are not of volcanic origin, may be the remnants of this old land.

The north-easterly trend of the eastern coast of our continent, as is the case with so many of the continents of the globe is far too speculative a subject to discuss here, but it is extremely interesting to get a line of volcanoes in this direction on the eastern coast of South Africa. This implies a line of weakness and an axis of folding in this direction, and it is therefore probable that the old land to the south-east of our present shore-line, after being cut down to near base-level by the ordinary erosive action of the atmosphere, dropped down by a monoclinal flexure beneath the waters. It has been the custom to invoke great faults to explain the contours of continents, but the shelving sea-bottom at present existing off our southern shores can best be explained, not by faulting, but by the gradual sinking of the sea-bottom without rupture.

ERNEST H. L. SCHWARZ

PETROLOGICAL EXAMINATION

OF THE

VOLCANIC ROCKS OF MATATIELE, GRIQUALAND EAST.

BY

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There is appended a short description of the various volcanic lavas and dykes as they appear in thin section, and of a few typical examples of the tuffs, from the Drakensberg, in the Division of Matatiele.

Generally speaking, the igneous rocks belong to one family, which is quite distinct from the dyke rocks that occur to the south, and two of which are described under class G. They are characterised by a peculiar method of crystallisation which can be followed from the glassy tachylites to the holocrystalline dolerites. Beginning with the glass, the first elements to form are the felspar laths. These are drawn together and form clusters or aggregates of felspar laths, or attract to themselves the small augite granules, and augite and felspar grow up together as an ophitic or pegmatitic grain. The augite is colourless, or with a slight ruddy tinge, but a bright green augite also occurs under particular circumstances. The felspar is labradorite, and as far as examined, never passes into anorthite, though the extinction angle is over 30° on the cleavage fragments parallel to the clinopinacoid. From a glassy rock thus constituted five fairly distinct classes of rock have been developed, which for convenience have been marked in the following descriptions by the letters A, B, C, D, E.

Class A.—The two elements in the glass, the felspar aggregates and the intergrowths of felspar and augite, have proceeded equally, yielding a rock made up of large aggregates of felspar lying in a ground mass of small felspar laths and augite, usually ophitic but sometimes pegmatitic.

Class B.—The grains composed of intergrowths of felspar and augite have been retarded in growth, so that the aggregates of felspar laths have gone on growing in the magma, till the latter consolidated as a microcrystalline base of felspar and green augite.

Class C.—The felspar aggregates have not formed, and the whole rock is now composed of an intergrowth, usually ophitic, of felspar laths and colourless augite.

Class D.—Is a peculiar class of rocks formed in the same way as those in Class A, but there is always a residual green glass, characterised by certain minerals, the nature of which is still doubtful.

Class E.—Rocks in this class have not crystallised out completely, but the augite and felspar form phenocrysts lying in a base of glass, more or less devitrified.

Except for the minute minerals in the residual glass of rocks in Class D, the volcanic rocks are composed of felspar, olivine and augite, either colourless or green, with magnetite. There is no brown mica, no hornblende, even in the form of uralite, no quartz, nor, in short, any of the accessory minerals that are always found on examining any small series of sections from the basic dyke rocks of the Colony, and I think I am justified in saying that the volcanic rocks of the Drakensberg, as far as the Matatiele Division is concerned, belong to a separate and self-contained order of effusion.

As regards nomenclature adopted, the terms dolerite and basalt are used according to whether the rock is mostly holocrystalline or has a glassy or devitrified base, and the terms diabase and melaphyre are used to denote the corresponding altered rocks. Alteration has been effected by percolating water, and while changing the felspars to zeolites and the augite to chlorite, at the same time it has filled the cavities with calcite, quartz, or zeolites. The alteration, however, has affected the rocks very capriciously; in some it is absent, while the cavities are filled with secondary minerals; in others, the rock is intensely altered, and the hollows are unfilled; in yet others the felspars may be unaltered and the augites changed to chlorite, slide No. 959, or the augite may be fresh and the felspars completely zeolitized, slides Nos. 925, 940.

The nature of the blow-holes as shown in thin sections is interesting; there are two varieties, those formed before, and those that were formed after the crystallization of the felspar laths. In the former case the hollows are rounded, and there is often a rim of matrix that has evidently cooled more rapidly than the bulk of the rock. In the latter the felspars freely project into the cavities, which are very irregular; laths, also, lie isolated in the calcite or zeolite which now fills the cavity, which may be due to the section passing through one of the projecting crystals. The difference of appearance of the two may be explained under the assumption that in the rock in which the felspars had already crystallised out when extrusion of the gas took place, this gas had been held in the magma below the critical temperature by pressure, and we may assume that this additional pressure may have been due to superincumbent flows of lavas that followed each other so quickly that the lower ones had not time to cool. If this is a true explanation, the temperature at which the felspars crystallised out would be very close to the critical temperature at which the rock-magna could no longer hold gas or water-vapour in occlusion. Professor Cohen* takes the view that the irregular cavities are formed by the leaching out of material and subsequent filling in by zeolites, but in slide No. 946 the two varieties occur together in such a way that it does not seem possible that they can be different in origin.

Judging from the macroscopic appearance of the rocks in the field, it seemed as if there was a considerable range of basicity in their composition. On the farm Manning, in the west, there were heavy olivine rocks, and in the east, on Zureka, flinty rocks like rhyolites, but under the microscope both these extremes are found to belong to the normal basic rocks of the series; the olivine, it is true in the one case, is present in unusually large quantities, but there is sufficient augite and felspar to retain the rock in the basic series, and the acid-looking rocks are quite normal basalts.

There are many other points of interest which would call for a reference here if this was a summary of work done on a larger series, but dealing only with the rocks from a limited area, the descriptions of the individual rocks will for the present have to suffice. Reference can only be made here to the pronounced radial growth of felspar, augite, and magnetite, which reaches its extreme development in slide No. 958; the order of crystallization of the felspar and augite giving ophitic or pegmatitic structures according to whether the augite encloses the perfectly formed felspars, or whether the felspar is contemporaneous or later than the augite; the peculiar hollow crystals of magnetite enclosing colourless glass, slide No. 924; and especially the structures and minerals in the small vein of glass, slide No. 919.

The clastic volcanic rocks, of which the description of a few slides is appended, call for very little notice here, after the description in the general part of this report. The most characteristic mineral of the tuffs and Cave Sandstone is microcline, very common in most of the South African granites. The epidote, tourmaline, rutile, and zircon may also be derived from granite or from metamorphosed sediments. In the earlier part of this report I have shown reason to infer that the Cave Sandstone and the tuffs that fill some of the vents, which are identical in composition, were derived from the shattering of pre-Cape and granite rocks, these latter being supposed to underlie the Table

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* Ueber einige eigenthümliche Melaphyr-Mandelsteine aus Sud-Afrika, Neues Jahrbuch, 1875, p. 113.

Mountain Series, which in turn underlies the Dwyka Conglomerate, and succeeding conformable series up to the Molteno Beds, in the Matatiele Division. Whether the Table Mountain Series is really present, of course, is uncertain; but at any rate the Cape or post-Cape rocks rest upon a basement which consists of granite and metamorphosed sediments. These basement rocks crop out on the surface on the east of the Umtamvoona River, in Natal, and it will be of the highest interest to see whether these Natal rocks contain the minerals necessary to form the Matatiele tuffs.

SYNOPSIS OF THE CLASSIFICATION ADOPTED.

Class A: Dolerite, with phenocrysts.
Class B: Basalt, with phenocrysts, microcrystalline base of felspar and green augite.
Class C: Dolerite, without phenocrysts.
Class D: Dolerite, with phenocrysts and a small amount of residual green glass.
Class E: Basalt, with glassy to microcrystalline base; no green augite.
Class F: Tachylite.
Class G: Dolerite, not belonging to the volcanic series.
Class H: Clastic volcanic rocks, tuffs, and agglomerates.

Amygdaloid, easternmost neck on Eyrie.

Slide No. 866
Class E

A compact, fine-grained crystalline rock, black, with many bright cleavage faces of felspar. A few large irregular amygdules filled with calcite and opal.

Under the Microscope:—

Felspar in laths, usually a single albite twin; alteration sets in along composition plane and proceeds outwards, or from the outside inwards, commencing with little vertical pegs, the former more common.

Augite represented by a mass of chlorite, with the original prismatic cleavage still discernible.

Olivine and glass now lost in general decomposition with calcite and green zeolitic minerals.

Magnetite in scattered crystals.

Amygdules filled with calcite. There is evidence that the matrix was originally distinctly more glassy in the neighbourhood of the larger amygdules.

Amygdaloid, easternmost neck on Eyrie.

Slide No. 867
Class E

The same appearance as the rock of slide No. 866

Under the microscope:—

Felspar in small laths, fairly fresh, magnetite in abundance; all other minerals altered to chlorite and calcite; glass also.

Zeolitization of felspars sets in from composition plane of the twins.

Granules of clear, colourless zeolite in the chlorite and calcite.

Amygdules with green zeolites and calcite; abundance of opaque specks, possibly magnetite.

Amygdaloid, Drakensberg, Eyrie.

Slide No. 870
Class E

A greyish green, fine-grained crystalline rock, no porphyritic elements apparent. Very small white patches, representing felspar. Rounded amygdules of calcite and colourless zeolites.

Under the Microscope:—

Felspar fairly fresh, in laths.

Augite represented by green patches of chlorite, often with glass-clear grains scattered through it.

Calcite filling in cavities with borders or included zones of zeolites.

Cavities irregular, with the felspar laths protruding into them.

Magnetite in abundance.

Lava from the Drakensberg on Eyrie.

Slide No. 871
Class E

A moderately fine-grained rock, with bright cleavage faces of felspar. Weathered somewhat.

Under the Microscope:—

Felspar in stout laths, idiomorphic, fairly fresh.

Augite grown ophitically with the felspar, usually in large individuals. Pinacoidal cleavage, irregular, but much more marked than the prismatic; the two can be well seen in transverse sections, and whereas no decomposition has set in along the prismatic, it has advanced steadily along the pinacoidal cleavage. In longitudinal sections, this pinacoidal cleavage makes the augite have much the appearance of olivine.

Olivine represented by patches of serpentine.

Greenish or yellowish glass with felted fibres of felspar.

Magnetite in large crystals, enclosing colourless glass; also to great extent the product of decomposition of olivine, for a serpentine centre is often seen.

Irregular cavities, lined with green fibrous zeolites, and filled with calcite, quartz, and colourless zeolites.

Slide No. 878 Included fragment in agglomerate neck, N'Quatsha.

Class E A black, compact, very minutely crystalline rock, with occasional bright faces of minerals, mostly felspar. A great quantity of vesicles, filled with clear calc spar and fibrous white zeolites.

Under the Microscope:—

Felspar, augite, and olivine imbedded in an opaque reddish matrix.

Felspar in slender or stout laths, often with a tendency to form radiating or geometric patterns; completely zeolitized.

Augite sometimes quite fresh, strong tendency of the smaller granules to adhere to the felspars; orthopinacoidal twinning sometimes present.

Olivine completely altered with a separation of magnetite, now reduced to red oxide; interior of the granules occupied by a clear, colourless mineral.

Amygdules filled with calcite, rounded, with a more glassy matrix than usual forming a rim.

Slide No. 879 Pipe-amygdaloid, Drakensberg, N'Quatsha.

Class E A red, drusy rock, splotched over with large aggregates of white felspar, often radially arranged. Branching blow-holes, 6 inches and more long; often not filled in.

Under the Microscope:—

Large phenocrysts of felspar, wholly altered, with twin lamellation still discernible, but sometimes in large aggregates. Individuals, often with abundant glass inclusions, ranged parallel to the crystal faces.

Small augite phenocrysts, changed to chlorite.

Rest of the rock consists of glass, strongly pigmented with haematite, and with a felted mass of felspar microlites and feathery devitrification growths.

Long amygdules of calcite.

Slide No. 880 From hill, S.W. of N'Quatsha's Nek road.

Class A A greenish black, moderately coarse crystalline rock, with felspars, black augite, and green fresh-looking olivine.

Under the Microscope:—

Porphyritic crystals of felspar, twinned according to the Carlsbad and albite laws, occasionally according to the pericline law, and on an oblique axis. Zoned, with more basic interior. Often untwinned, or a broad, non-lamellated crystal twinned on a narrow, lamellated one. The larger crystals have linear inclusions of glass, and occasionally augite, parallel to the crystal faces. The larger, stouter crystals often form aggregates. Laths of felspar always twinned according to the albite law, sections parallel to the clinopinacoid show basal cleavage.

Augite in large individuals, forming a base for the smaller felspars, but seldom showing crystal faces.

Olivine in large rounded grains, with serpentine alteration along cracks, sometimes shows remarkably sharp crystal faces.

Magnetite in long linear aggregates or separate octahedra, sometimes as shapeless lumps; usually found in the residual glass. Larger octahedra sometimes with colourless, glass-clear centre. Matrix either brown and glassy, with small, white, highly refractive granules, or microcrystalline, with felspar laths and augite.

Average size of the crystals in millimetres:—

Felspar phenocrysts	3.2	x	.8
„ aggregates	4	x	1.6
„ laths	.8	x	.25
Olivine	1.6	x	.8

From dolerite sheet, S.W. of N'Quatsha's
Slide No. 881 Nek road.
Class **B** A glossy black rock, with large fresh crystals of felspar, with bright cleavage faces; matrix stony, with bright specks in it.

Under the Microscope:—

Felspar in porphyritic crystals, usually much broken, and sometimes in granular aggregates, enclosing glass between the granules. Shadowy twin-lamellation is sometimes seen in the larger crystals. The inclusions are usually of glass, but augite is also present, and the latter seems to be of earlier origin than in the rocks of Class A. Felspar in the ground-mass is in stumpy laths, with the usual albite twinning. The laths are indented by the augite, but ophitic intergrowth also occurs.

Augite is in small bright granules, light green, and seldom shows crystal faces; it forms with the felspar and magnetite the bulk of the rock.

Olivine in large rounded lumps, much altered to serpentine, which may be light green or yellow, and sometimes with rim of magnetite.

A little residual glass, with long needles of forming felspar and magnetite. There is also present small quantities of a green glass, with spherulitic devitrifications, and also a certain amount of a clear, colourless glass.

Average dimensions of crystals in millimetres:—

Felspar aggregates, 2 x 1.6; felspar phenocrysts, 1.4 x .6; felspar laths, .17 x .03, .08 x .015, .06 x .01; augite, .05 x .02; olivine, .8 x .6; magnetite varies from .04 to .005.

Slide No. 882 — From dolerite sheet capping hill between Bramwell and Dell Cranney.

Class **B** — A glassy, black rock, with large fresh crystals of felspar, with bright cleavage faces. Matrix stony, with bright specks in it, somewhat oily lustre.

Under the Microscope:—

Felspar in porphyritic crystals, with inclusions of glass and augite ranged parallel to the crystal faces. Irregularly shaped lumps of felspar, with scattered inclusions; no twinning in these. In the larger crystals, pericline lamellation is sometimes present with the albite.

Olivine in large lumps, completely changed to serpentine.

These porphyritic elements are scattered throughout an extremely fine granular matrix, composed of green augite and felspar. The felspar laths are stumpy, and the augite, although seldom showing faces, is clearly not subsequent to the felspar. A small amount of interstitial glass occurs round the minute crystalline elements.

There are also patches of a brown or inky-grey glass, through which are scattered broad, untwinned crystals of felspar; augite, often sharply idiomorphic, with octahedra of magnetite adhering to the crystals; and some rounded patches of serpentine, representing olivine. Incipient devitrification is evident in this glass. There are also patches of colourless glass, similar to that often seen in the interior of larger crystals of magnetite, and a light green glass, with spherulitic growths.

Average dimensions of crystals in millimetres:—

Felspar, porphyritic, .8 x .3, 1.0 x .25; felspar, laths, .035 x .01, .06 x .06; olivine, .5 x .5; augite, .03 x .025, .14 x .035; magnetite, .06 x .02, .04 x .04.

Slide No. 889 — Fragment from agglomerate, volcanic neck on the east of the river on N'Quatsha.

Class **E** — A purplish red, stony rock, with occasional dull felspar laths. Large aggregates of felspar laths, usually in radiating bundles. A great number of vesicles filled with calcite in the lower half; these are pipe-shaped, ¼ inch in diameter.

Under the Microscope:—

Felted mass of small felspar laths, and feathery radiating groups of the same. A larger generation of stout laths, and a fourth or oldest generation of stout columnar crystals, often gathered together into large aggregates, and having crowds of glass inclusions parallel to their crystal faces.

Augite in moderately abundant, small crystals, replaced by a non-pleochroic green mineral.

Amygdules filled with calcite, with green borders; the matrix is more glassy in the neighbourhood of the larger blow-holes. The holes are rounded, sometimes with vertical projections; also linear series of blow-holes.

Slide No. 891 Dolerite from westernmost conical hill on Eyrie.

Class A A greenish black rock, with felted mass of glassy laths of felspar, and also larger crystals, with bright cleavage faces. Fine grained.

Under the Microscope:—

Felspar in ill-formed phenocrysts and in aggregates, in which the boundaries of the individual crystals are irregular and rounded. The larger crystals often unlaminated, but with zones of growth; pericline twinning sometimes shows as well as the more common albite. Glass inclusions either parallel to the crystal faces or irregularly scattered throughout the central portion. The crystals sometimes with quite irregular boundaries, either due to corrosion or to the fact that the outside growth of the crystal filled up irregular spaces in the magma (leptomorphous).

Augite forming a base for the smaller felspars.

Olivine fresh, with slight amount of serpentinization.

A very little residual glass, with felspar microlites and magnetite.

Dolerite dyke behind Belmont house.

Slide No. 892 A very fine-grained black rock, with bright

Class G cleavage faces of minerals, mostly with rounded outline.

Under the Microscope:—

Felspar in laths, with indefinite terminations often corroded; others are dusty with inclusions. Usually a single twin, but pericline twinning is occasionally also present.

Augite sometimes included in the felspar. Usually in large grains, which are invaded by the ends of felspar laths. Alters sometimes to strongly pleochroic brown hornblende, with a green border; single refraction of the hornblende lower, but double refraction higher than the augite, sometimes fibrous (uralite), but usually massive.

Olivine mostly changed to serpentine, only small centres of unaltered substance left.

Magnetite in largish octahedra, with colourless isotropic centres, and as a fine dust, Ilmenite.

Cloudy patches in between the mosaic of crystals seem to represent residual glass, but the substance is probably a late development of felspar.

Average dimensions of crystals in millimetres:—

Felspar, .2 x .12, .28 x .04; augite, .13 x .23, .8 x .09; olivine, .1 x .07; magnetite, .07.

Dolerite from Rankakata's Nek.

Slide No. 893
Class D

A moderately coarse-grained rock, black, with greenish black augite, olivine, and in less proportion felspar, glassy, but discoloured brown.

Under the Microscope:—

Felspars in large aggregates made up of laths, with or without inclusion of augite in the angles; also stout columnar crystals, which show strong cleavage parallel to the basal plane. The ends of the smaller laths often embraced by an isotropic substance pseudomorphous after the felspar, with very low single refraction, may be referred to analcite; same mineral also forms thin laths adherent to the larger felspars. The felspar is a basic labradorite showing the ordinary twin-lamellation.

Augite is sometimes with well-formed crystal faces, but usually formed independently of, though later than, the felspars. Frequently with the usual orthopinacoidal twinning. A colourless or slightly ruddy mineral.

Olivine in moderate-sized individuals, usually fresh, with a little green serpentine forming along cleavage cracks. Outline rounded, never crystalline.

Magnetite in large crystals, enclosing felspar and augite.

Apatite in very long needles or in stouter crystals, showing hexagonal sections; basal cleavage very marked. Cavities with bubbles in them in the centre, elongated in direction of length of crystal; occurs mostly in the glass.

Small amount of green, granular glass, with developing hollow crystals of felspar, apatite, needles of a highly refractive mineral, and an isotropic substance, possibly analcite.

Coarsely crystalline dolerite from Rankakata's Nek.

Slide No. 894
Class D

A fairly coarse-grained, black rock, with large porphyritic crystals of augite, with well-formed faces. Thin laths of glassy felspar; small fresh olivine crystals.

Under the Microscope:—

Felspars large phenocrysts, zoned and untwinned, or with shadowy lamellation. The lath-shaped individuals aggregated in bunches of columnar crystals, rarely granulated. The sides of the felspar crystals are often corroded by the green glass, which penetrates the substance of the crystal in the form of pegs.

Augite in very large individuals, forming an ophitic base for the felspars. In the glass there is a more ferruginous augite in small idiomorphic crystals, surrounded by crystals of iron ore.

Olivine in large lumps, seemingly later than the felspar, against which it abuts.

Glass white and transparent, or green and fibrous, the latter variety often with ill-formed laths of felspar, sometimes hollow; needles of apatite; augite usually with magnetite, and magnetite in separate crystals, and sometimes ilmenite.

Slide No. 901 Dolerite from the neck in Cave Sandstone west of the kloof on Glen Alfred.

Class B A fine-grained, holocrystalline rock. Small specimen rather weathered.

Under the Microscope:—

Felspar in stumpy laths, imbedded in a matrix, now changed to chlorite, serpentine, and calcite.

Felspar is clouded, but not decomposed.

Magnetite.

There appears to have been some residual glass, but this is now entirely altered by devitrification.

Slide No. 903 Amygdaloid in tuff neck on ridge between Deer Park and Glen Alfred.

Class E Greyish green, compact, crystalline rock, with bright cleavage faces of minerals. No porphyritic crystals apparent. Long amygdules, filled in with calcite and quartz, with a hackly fracture.

Under the Microscope:—

Laths of felspar, with augite in a glassy base, very much altered.

Felspar completely zeolitized, sometimes with calcite, by infiltration.

Augite altered to chlorite and calcite.

Olivine, no recognisable forms.

Iron ore in very small quantity.

Amygdules filled with zeolites and carbonates, the latter forming a brown granular mass with the high refraction of the carbonates.

Slide No. 904 Amygdaloid in tuff neck between Deer Park and Glen Alfred.

Class E A light green rock, with large felspars. Small flecks of blood-red iron ore and pyrites. Small amygdules.

Under the Microscope:—

Felspar in fairly large laths, with a tendency to form rosettes, or a group with one very long lath and a bunch of smaller ones crossing it in the centre.

Augite in granules lying scattered or clustering about the felspar laths; changed to a green chloritic mineral with calcite.

A very large amount of brown glass, with small microlitic laths of felspar and strings of iron-ore crystals. A good deal of calcite in the glass, which may represent original augite or olivine, or may be merely an infiltration.

Dolerite in tuff neck between Deer Park and
Slide No. 905 Glen Alfred.
Class B A compact, greenish grey crystalline rock,
with small irregular spaces filled with quartz and
opal.

Under the Microscope:—

The same as slide No. 901, but the felspar rather fresher.

Dolerite from the high volcano on Deer Park.
Slide No. 906 A dark grey, compact, crystalline rock, with
Class A glassy felspars and a little green olivine.

Under the Microscope:—

Large phenocrysts of felspar, with zones of growth and with crowds of glass inclusions arranged parallel to the crystal faces. Larger crystals show twinning on the Carlsbad law. Aggregations of large phenocrysts of felspar; sometimes with irregular and corroded boundaries and surrounded by augite; also independent laths, intergrown with augite.

Augite, sometimes small idiomorphic crystals in the glass, with minute octahedra of magnetite sticking to them; usually in large individuals, forming a base for the felspar laths.

Large olivine altered to some extent to serpentine; in rounded grains.

Magnetite often with colourless, transparent centres.

Residual glass, devitrified with fibrous microlites very sparingly present.

Amygdaloid, second lava flow, volcano No. 4
Slide No. 907 Deer Park.
Class E A greenish grey or black rock, weathering to
a light maroon. Stony, with very few crystalline
faces.

Under the Microscope:—

Matrix a brown glass, devitrified with feathery growths, microcrystalline in parts. A few small phenocrysts of felspar and less frequently of augite; these altered completely, while still retaining their shape.

Slide No. 908 Ropy surface of first lava flow, volcano No. 4 on Deer Park.

Class E A puce-coloured, stony rock, with irregular flecks of dark green material, with light powdery centres, large, irregular cavities, filled in with a soft white radiating zeolite; surface of ropes smooth, sometimes ribbed. The piece selected for sectioning was without vesicles.

Under the Microscope:—

Matrix stony, with reddish grey spherules of a granular substance arranged in radiating fibres and a more dense granular substance between.

An irregular system of cracks filled in with haematite.

Stout crystals and laths of felspar, usually grouped in bunches. Augite scarce, in idiomorphic crystals, also in small granules between the laths of felspar; even the larger crystals show a tendency to cling to the felspars.

Both felspar and augite are completely altered.

Slide No. 909 Dyke in amygdaloid, W. of Makomereng.

Class A dark, grey-green rock, with bright felspar laths.

Under the Microscope:—

Felspar laths fairly fresh, but the rest of the rock-substance represented by cloudy alterations; augite, olivine, magnetite, and glass.

Slide No. 910 Crushed-up material on north side of dyke, west of Makomereng.

Class C Fresh purplish rock, with bright cleavage faces of felspar, sometimes discoloured brown.

Under the Microscope:—

Felspar in laths with twin lamellation still visible, though now completely altered.

Augite fills in base ophitically; altered on the outside with separation of magnetite.

A good deal of opaque red material, which may represent some original constituent by alteration, or may be interstitial glass.

A few small amygdules.

The whole much altered, with calcite infiltration.

Slide No. 911 Amygdaloid from Drakensberg, west of Makomereng.

Class E A compact, blue-black rock, weathering brown, with dull laths of felspar. Many long-drawn-out amygdules filled with various zeolites, hackly quartz, and opal.

Under the Microscope:—

Felspar porphyritic crystals; twinning still discernible, but altered to a mosaic of alteration products, scolecite, etc. Small laths, stumpy, with slight tendency to form lateral aggregates.

Augite in small grains, usually adherent to the felspars.

Large crystals of olivine, altered to serpentine.

Brown glass filling in all interstices, with felspar microlites in feathery bunches, with minute bright specks of augite

Slide No. 915
Class D

Centre of weathering, north side of dyke, south of the shop Makomereng, on the farm Retreat.

A fine crystalline black rock, with no porphyritic elements apparent, but augite in moderately large crystals.

Under the Microscope:—

Large phenocrysts and aggregates of felspar, often without lamellar twinning, or in the form of a single Carlsbad twin, with pericline lamellations. Individuals with albite lamellation also twinned after the Carlsbad law. Long laths of felspar and aggregates either wholly irregular or formed by lateral accretion. Light green patches of non-pleochroic green material resulting from the decomposition of the felspars.

Large bits of a strongly pleochroic green material, with cleavage like that of mica, extinction always parallel to the cleavage, and double refraction a little less than augite.

Microcrystalline base, formed of felspar laths and augite, now entirely changed to chlorite.

A large number of small grains and aggregates of grains of epidote, sometimes in fairly large crystals, glass clear and colourless, with strong basal cleavage, or more usually in dusty, yellowish granules. Has characteristic high double refraction, but not so high as sphene for which some of the grains from their colour and shape might be mistaken.

Spaces occupied by brown glass with fibrous bundles of developing felspar, hollow crystals of felspar, green alteration minerals, and rounded bits of quartz. Whether these last are bits picked up by the dyke, or original constituents, or again, secondary secretions, it is impossible to say. Inclusions of sandstone also occur.

Slide No. 916
Class E

Dolerite from middle ridge, Makomereng.

A compact, grey, crystalline rock, with bright cleavage faces of minerals. Weathers with separation of haematite.

Under the Microscope:—

Felspar in laths, sometimes fresh, but mostly altered to green and white zeolites.

Augite, ophitic, usually perfectly fresh.

Olivine, recognisable by its form, though wholly altered to serpentine or chlorite on outside, and calcite in the interior.

Glass, white, with felspar laths encrusted with small granules of augite; magnetite altered to haematite; independent grains of augite; and amygdules, with green border of strongly pleochroic green substance, probably delessite, cloudy carbonates in the interior.

Slide No. 917 Dolerite dyke above middle ridge, north of Makomereng.

Class E A moderately coarse-grained crystalline rock, somewhat weathered, in which light olive-green olivines and glassy felspars in laths and aggregates can be discerned.

Under the Microscope:—

Felspar in porphyritic lumps, granulated, and with outer zones later than the augite; frequently zoned.

The finer felspar laths are clearly earlier than the augite, which is grown ophitically round them. In places there is pegmatitic or simultaneous intergrowth, when the laths do not have their crystalline boundaries, but usually it is not so.

Augite, light-ruddy variety, with usual high extinction.

Olivine in very large grains, with the usual cracks and serpentine alterations; very fresh in the larger bits, but smaller ones altered to serpentine and haematite.

A little colourless glass, with felted microlites and magnetite. Long needles of a highly refractive mineral, with extremely small cross sections, run through the glass into the serpentine and felspars.

Slide No. 918 Dolerite flow on the amygdaloid, ridge to the west of Makomereng. Part of a centre of spheroidal weathering.

Class A A moderately fine-grained crystalline rock, with crystals and laths of felspar, and larger patches of a brownish mineral (augite).

Under the Microscope:—

Felspar in large lumps, granulated, with or without inclusions. Smaller laths seldom with full natural boundaries, being intergrown contemporaneously with the augite; also arranged in irregular aggregates.

Augite, colourless, with strong relief; twinned, sometimes encloses olivine.

Olivine, perfectly fresh, or serpentinised, or altered to serpentine and magnetite, or entirely magnetite.

Original magnetite; often transparent red films of iron-ore.

A good deal of interstitial bright green material, may represent glass.

Slide No. 919
Class F

Tachylite, occurring as a vein in the dolerite forming the great dyke west of Makomereng.

A black glass, without lustre, in which there are embedded small bright porphyritic crystals. Brownish veins, branching. On the outside of the lump there is a smooth greenish skin, about $\frac{1}{8}$-inch thick. In a larger specimen the veins are green, bordered with black, with a black centre, and the brown is in spherulitic groups in the black ground mass.

Under the Microscope:—

A black glass, with porphyritic crystals of felspar and augite, and segregation veins of green augite and felspar.

Matrix varies from an opaque black glass through yellow-brown to white. Irregular cracks, not perlitic. Incipient devitrification, spherical, forming small rounded blotches, lighter than the surrounding glass. Scattered black dots, magnetite in all probability, aggregate along the cracks.

Felspar, with stout rectangular sections, with high extinction indicating a basic labradorite; often with a sharply defined outer border of a less basic variety. Either in single crystals, or joined side by side, or joined anyhow, or finally in large, close aggregates. Sometimes in fine laths, with small crystals of augite adherent, the whole making a separate porphyritic element, and sometimes the grains of augite run together, forming one individual when an ophitic element is produced.

Augite, in multiple intergrowths, or in separate individuals, showing the orthopinacoidal twinning. Sometimes with sharp crystal faces. Fresh and strongly refractive, high double refraction; colour slightly ruddy.

Some spaces with prism and pyramid faces now filled in with serpentine represent olivine, as the augite is always unaltered.

Segregation veins, symmetrical in section. On the outside there is a zone of opaque, black glass, inside of which there is a zone of incipient globular devitrifications which contain minute green augite granules and felspar crystallites. This merges on the inside into a layer of granular material, consisting of the same minute green augites and felspars with a few grains of magnetite. Then in order, come:—a zone of magnetite octahedra; a granular layer more cloudy than the former one, again with minute green augite and felspar. Large laths of felspar are seen indistinctly through the cloud of granules, standing up at right angles to the sides of the veins. Inside of these comes a zone of columnar crystals of green augite, standing, some at right angles to the sides of the vein, others at all angles. The centre of vein consists of felspar, labradorite, in large crystals, with albite twinning, very fresh and distinct, with occasional brown discolouration. The augite needles were all formed before the consolidation of the felspar, which seems to have remained in a molten state in the centre of the vein for some time after the augite was formed; very little residual glass was left when the felspar finally crystallized out.

The porphyritic crystals and grains in the glass penetrate and lie across the segregation veins, which are unaffected by them.

Calcite, magnetite, and colourless glass also occur in the centre of the veins. The last is sometimes crowded with granules, at other times is glass-clear. With the glass-clear variety there are often thin films of purplish glass which is sometimes also found between the felspar crystals.

The minute augite granules in the divitrified glass are the same as the green augite in the centre of the veins; the same mineral is found also in the microcrystalline base of rocks classed under B. This augite occurs in the veins in long columns, terminated by well-formed dome faces, and with sections usually octagonal, showing that the prism and two pinacoids are more or less equally developed. A rough cleavage is sometimes shown though the columns are so minute, and it seems to be parallel to the orthopinacoid. Very large examples measure .1 x .3 millimetres, but an average column measures .2 millimetres long by .02 in section; the granules are about .002 millimetres in diameter. The colour is a vivid green, with a very slight change to a more yellowish green; the mineral, therefore, is not acmite or aegirine, but may be classed as diopside. It is in one instance seen to be intergrown with the light ruddy variety.

Slide No. 920 Dolerite from great dyke in kloof west of Makomereng.

Class D A dark grey-black crystalline rock, in which the lath-shaped glassy felspars are conspicuous. No porphyritic elements can be noticed.

Under the Microscope:—

Felspar in stout crystals, often aggregated into large clusters. Clearly earlier than the augite, though grains of the latter often intrude into the substance of the felspar, showing that the outer layers of the latter were formed after the augite was crystallised

Felspar forms by far the largest proportion of the constituent minerals.

Augite, with slight ruddy colour, in small grains. Fairly large patches of serpentine and calcite represent original olivine; augite granules, unaltered, enclosed in the alteration products.

Magnetite in irregular grains or long threads.

Glass, green granular material with felspar laths. The latter often hollow forms. A glass-clear, long, lath-shaped mineral, often in radiating groups, square ends and square sections. Also an isotropic substance, apparently pseudomorphous after felspar, for it occurs in small laths, possibly analcite.

Amygdaloid, from lava neck, east of Trappists'
Slide No. 923 Mission Station, George Moshesh's Country.
Class E A bright grey, very close crystalline rock, showing a felting of small felspar laths; small round vesicles filled in with white zeolites.

Under the Microscope:—

Porphyritic crystals of felspar and augite in a glassy matrix.

Felspar in laths, and in larger crystals, zeolitized.

Augite in granules, fresh. Also in porphyritic crystals altered to a green substance, fibrous, with pleochroism from dark grass-green to colourless, delessite.

Glass, brown, in fair quantities.

From great volcanic neck between George
Slide No. 924 Moshesh's Country and N'Kau's.
Class A A fine-grained, dark-grey crystalline rock in which there are embedded small porphyritic crystals of felspar.

Under the Microscope:—

Porphyritic crystals of felspar, augite and olivine, and aggregates of felspar; interstitial brown glass.

Porphyritic felspar in very irregular forms, freely indented by the augite; usually in stout crystals, aggregated in lumps with or without glass in between. Sometimes the boundaries of the constituent felspars in the aggregates are rounded. Larger grains of felspar are often without twin lamellation, or this may appear shadowy; strong zoning in such grains, and edges rounded or corroded as if they were the first-formed mineral, and had remained some time floating about in the molten magma.

Felspar of matrix in small laths, symmetric extinction of these on either side of the twin plane goes over 30°. More stumpy laths twinned according to the Carlsbad as well as the albite law. Laths show a tendency to form pegmatitic intergrowth with the augite.

Augite of matrix in small granules, with a slight ruddy tinge.

Olivine varies in freshness, alters to a green serpentine.

A yellowish green alteration product may also represent original olivine.

Glass brown, but under high powers resolved into a colourless base, with crowds of brown specks, and a fibrous, colourless mineral, probably incipient felspar.

Magnetite mostly occurs in the glass, frequently with enclosures of colourless granular glass.

Dolerite neck between George Moshesh's
Slide No. 925 Country and N'Kau's.
Class E A puce-coloured rock with flecks of green glass.

Felspar in laths completely zeolitized, much light green alteration products.

Augite quite fresh in rounded grains.

A great quantity of green alteration material, probably serpentine after olivine. The large quantity of this reminds one of the dolerite flow to the south, on Manning, slide No. 929, which is the only fresh rock in the district containing so much olivine.

A fair quantity of glass, devitrified, with flecks of magnetite altered to haematite.

Dolerite from ridge about two miles north of
Slide No. 927 Hlaganello's stadt.
Class A A very coarse-grained crystalline black rock, with large and numerous phenocrysts of glassy felspar.

Under the Microscope:—

Felspar phenocrysts zoned, and twinned according to the albite, Carlsbad and pericline laws. Frequently forms large aggregates which are granulated or made up of felspars with rounded or irregular borders. Also small felspar laths.

Augite usually with ophitic intergrowth of small felspar laths, but sometimes alone. In the latter case the augite is often twinned along the usual orthopinacoid plane, or two crystals with different optical orientation are intergrown irregularly parallel to this plane.

Olivine represented by patches of serpentine; magnetite in hollow growth forms.

Matrix, a fine-grained aggregate of felspar laths and augite granules with patches of colourless glass rendered cloudy with specks of magnetite.

Dolerite on western hill of Manning.
Slide No. 929 A very heavy crystalline rock, moderately
Class D coarse-grained. Much green olivine, black augite and felspar laths.

Under the Microscope:—

Felspar and olivine embedded ophitically in augite. Felspar in long laths, showing often the pericline as well as the albite twinning; no definite zoning but a gradual increase of basicity in the interior of some. Lammellæ sometimes bent, indicative of strain after crystallisation.

Augite in large individuals, greyish.

Olivine very abundant, but mostly in granules of moderate size, no large lumps. Mostly fresh, but alteration commencing along cracks.

A very small amount of greenish glass, containing hollow laths of felspar and needles of a highly refractive indeterminate mineral.

Dolerite from central hill on Manning.

Slide No. 930 A moderately, fine-grained black rock in a
Class E block about 1½ inches thick, with a brownish-red rough, weathered coat on either side. Large felspars, with bright cleavage faces.

Under the Microscope:—

Felspar in large, stout crystals and aggregates; also smaller laths and irregular forms intergrown with augite. The larger crystals have a great number of glass inclusions ranged parallel to their crystal faces.

Augite only in grains ophitic with the felspar laths.

A great amount of olivine in irregular grains, mostly altered to serpentine.

Magnetite in long threads.

A fair amount of interstitial matter consisting of devitrified glass with fibrous radiating groups, which may be split up under high powers into crystallites of felspar and minute granules of augite.

Dolerite from easternmost hill on Manning.

Slide No. 931 A black crystalline rock with much glassy
Class E felspar in moderately large crystals.

Under the microscope:—

Felspar, augite and olivine in a glassy base; the last with well-formed small laths of felspar; otherwise the same as slide No. 930.

Dolerite overlooking Oude Corner's Camp.

Slide No. 932 A greenish black, moderately coarse crystal-
Class D line rock; ground colour black, augite, with clear crystals of felspar and green olivine.

Under the Microscope:—

The greater portion of the rock consists of an ophitic intergrowth of small laths of felspar and augite, the latter often in large individuals.

A small amount of green glass with the usual acicular, long thin needles of an indeterminate highly refractive mineral, occuring in parallel and radiating groups. The larger felspars have often a zone of a mineral of lower refractive index on the outside, possibly a partial pseudomorph of scolecite; bits of this are sometimes broken away from the felspar as if by movement after consolidation.

Dolerite from south side of Jordan River.

Slide No. 933
Class D

A black crystalline rock with large glassy felspars.

Under the Microscope:—

Felspars in stout laths, very abundant.

Augite in large individuals enclosing the felspars ophitically; quite fresh.

Olivine represented by a few patches of serpentine; occasionally a small centre of unaltered mineral is present.

Magnetite in fairly large rods and irregular lumps. Green glass with spherulitic devitrification; hollow laths of a mineral, probably pseudomorphous after a felspar, for the large felspars that protrude into the glass have a zone of the same material as the substance of the hollow crystals in optical continuity with them; the mineral is sometimes isotropic or with straight extinction, and from this grades gradually into recognisable felspar; it is probably a zeolite. There are often acicular crystals of extreme tenuity, and with high refraction, scattered through the glass in parallel groups.

Lava flow, York, near Ongeluk's Nek.

Slide No. 938
Class D

A slate-coloured rock; very compact, crystalline base, full of large vesicles of an irregular shape, lined with a rough brown crust and filled with a soft, black substance and films of calcite.

Under the Microscope:—

Augite and felspar in stony matrix, both quite fresh.

Porphyritic felspar in square forms and long laths consisting of a single albite twin and odd-shaped bits without any crystalline shape, leptomorphous.

Augite of the light ruddy variety, in granules.

Matrix, a greenish glass with abundant hollow crystals of felspar, magnetite, and colourless needles of a highly refractive mineral, minute laths of felspar, and crowds of opaque specks.

A warm brown to olive green mineral, probably serpentine, may represent original olivine.

Amygdaloid, N. side of York.

Slide No. 939
Class E

A heavy black rock, with much brown, glassy material. Rounded portions of black stony matrix with minute bright laths of felspar. A few cavities filled with a brown earthy material.

Under the Microscope:—

Felspar in large broad crystals, zoned, also irregular bits with shadowy lamellation; aggregates usually granulated; qu fresh. Smaller laths stout, with sharp terminations.

Augite in large crystals, forming base for the felspar laths (ophitic structure); quite fresh; frequently twinned. Smaller crystals in glassy matrix, idiomorphic, slightly more refractive than the larger forms, and with little magnetite octahedra sticking to them.

Green or yellow very pleochroic serpentine in fair quantity, represents olivine.

Glass full of black specks, arranged like iron filings in a magnetic field. Long shreds of magnetite, also in small crystals. A small amount of alteration in the glass, turning it yellow.

Amygdules with yellow borders of fibrous zeolites, besides the centre consisting of colourless zeolites, carbonates and green minerals.

Slide No. 940 Amygdaloid, east peak overlooking Ongeluk's Nek.

Class E A ruddy buff-coloured stony rock with abundant bright cleavage faces of glassy felspar, many rounded, and irregular cavities filled in with various zeolites, some radiating, others occupying the whole space of the vesicle; some white, some glass-clear, some discoloured brown.

Felspar in long laths, completely zeolitized.

Augite quite fresh, in granular form, colourless, with slight ruddy tinge. Very abundant. A small amount of chloritization along cracks.

Olivine perhaps represented by patches of indeterminate zeolitic minerals surrounded by rim of magnetite.

Interstitial glass in fair quantity, coloured red with flecks and strings of hæmatite, a reduction product of magnetite.

Irregular spaces filled in with radiating clusters of colourless zeolites; these are doubtfully blow-holes, as the felspar laths project freely into the filled-up cavity; they may be portions of the glassy magma that have been leached out, as Cohen holds, see *supra*, p. 67.

Slide No. 941 Dolerite dyke in amygdaloid, Ongeluk's Nek road.

Class E A compact crystalline rock, black with much felspar in small laths.

Under the Microscope:—

Felspar in stout laths, often untwinned, but zoned; sharp terminations. Aggregates usually by juxtaposition of crystals with a small amount of glass between constituents; sometimes the aggregates consist of granules of felspar.

Augite ophitic with the felspar; quite fresh.

Olivine, always altered to serpentine.

Glass, green, with white shreds of forming felspar; magnetite specks crowded round these latter.

Magnetite crystals and threads, and hollow crystals of felspar also dispersed through the glass.

Columnar basalt from York volcano.

Slide No. 944
Class E

A fine-grained crystalline black rock; no porphyritic crystals apparent. A few glassy felspars.

Under the Microscope:—

Fine-grained matrix of felspar, augite and glass, with porphyritic felspar and olivine.

Felspar in stout crystals, sometimes in linear aggregates or in grains massed together. Laths in matrix short and stumpy, with definite terminations; sometimes hollow forms or with small enclosures of augite and glass.

Augite porphyritic and in granules clustered round the felspar laths.

Olivine represented by green or yellow serpentine.

Brown granular glass, with strings of magnetite and shreds of forming felspar.

Amygdaloid, south-west side of York volcano.

Slide No. 945
Class E

A light, puce-coloured stony rock, with small irregular flecks of dark green material, also a less conspicuous light green material. Long amygdules filled in with white and green zeolites.

Under the Microscope:—

Felspar in long thin laths or in stout and stumpy forms, with a tendency to form aggregates; larger crystals with clusters of glass inclusions parallel to their longer diameter, which sometimes run together, cutting the crystal into separate shreds. The interior of the felspars altered to a light green zeolitic substance.

Augite, with a slightly greenish tinge and very high refraction, similar to the granules in the base of group B; sometimes idiomorphic, but more usually intergrown with the smaller laths. The very high refraction makes the irregular cracks in the small crystals very prominent, but no trace of alteration has taken place along them.

Olivine changed to fibrous serpentine; crystals have sharp outlines, and are generally not rounded. In some cases there has been a separation of iron-ore. Matrix in fair quantity; it is a cloudy brown glass with a good deal of small crystals of magnetite scattered through it.

Irregular cavities filled in with light green and colourless cloudy materials, the former usually lining the cavity with a fibrous layer. Felspar laths project freely into the cavity.

Slide Nos.
946, 947
Class B

Amygdaloid lava, east side of York volcano.

A stony grey rock, with small rounded and irregular vesicles filled with zeolites with a green border; veins of pyrites.

Under the Microscope:—

Porphyritic crystals of felspar and olivine scattered through a fine granular matrix of green augite, felspar and glass.

Felspar in porphyritic crystals, stout forms and long laths, the former frequently run together into large aggregates. Glass inclusions parallel to the long axis of the felspars, often joined up and occupying nearly as much space as the felspar itself. The clusters are sometimes compact, but more often the crystals are joined together at all angles, enclosing much matrix. The porphyritic crystals are altered, but never so much but that the original albite twinning is seen through the clouds of minute secondary crystals.

Olivine in large irregular lumps completely changed to fibrous serpentine.

Matrix, consisting of thin, ill-formed laths of felspar, often intergrown pegmatitically with the augite. The latter in small granules usually, with strong relief and a slight greenish tinge.

Glass is a greenish granular substance with flecks of haematite. Well-rounded blow-holes, often with branching tubules stretching out towards neighbouring ones, also irregular cavities into which the ends of the felspars project. Both varieties filled in with a yellowish green zeolite, fibrous and radiating.

Lava-flow on top of hill near York volcano.

Slide No. 948
Class B

A light, puce-coloured rock, with dark green irregular flecks showing crystal-faces.

Under the Microscope:—

Large clusters of porphyritic crystals of felspar much altered in the interior with development of comparatively large crystals of a greenish mineral. Substance of the crystal, however, is still unchanged. Small laths of the matrix without alteration.

Matrix, fine grained, consisting of felspar laths, augite and glass, in which there are rounded blow-holes and irregular cavities filled in with green zeolites and calcite.

Augite in small granules, with strong relief, and a slight greenish tinge.

Olivine not recognisable.

Interstitial glass, brownish, granular, with flecks of hæmatite.

Slide No. 949
Class B

Dyke, southernmost of the three on the north of Inverness.

A stony rock, greenish black in colour, with small crystals of felspar in fair abundance, showing bright cleavage faces. Pyrites occurs in small rounded pockets along cracks or joints.

Under the Microscope:—

Porphyritic felspar and olivine in an extremely fine granular matrix of augite, felspar, and magnetite; no glass.

Felspar in single large crystals, 1 x 1.5 millimetres in section, with entire crystal faces, but parts often slipped off along the pinacoidal cleavage, and lying in the matrix adjoining. Aggregates of smaller crystals showing albite and pericline twinning; intergrowths along the latter axis. Also in long laths, with inclusions of augite granules. Larger crystals only occasionally zoned.

Olivine in sharp crystal forms, altered to green serpentine.

Matrix, a fine intergrowth of felspar and green augite, the felspar slightly later than the augite.

Augite, strong relief, tinted a faint green, averaging .02 millimetres in diameter. Felspar tending to lath shape, but boundaries controlled by the augite grains; twin-lamellation not always present. The felspar is not so basic a labradorite as is usual in the rocks of this district.

Magnetite in section showing as grains about half the size of the augite, and about a quarter as abundant.

Slide No. 950
Class B

Lava above the Cave Sandstone intercalation, north bank of the Mabele River, west of York house.

A compact, greyish-black rock; no crystalline structure apparent. Rounded patches of a brown siliceous substance, about $\frac{1}{4}$ inch in diameter, occur all over the surface of the rock. Quantities of small rounded vesicles, filled with zeolites.

Under the Microscope:—

Large idiomorphic crystals and aggregates of felspar, fresh, but much fractured. The aggregates are intergrowths, and are not granulated; both phenocrysts and aggregates contain a little of the granular augite matrix.

Patches of colourless zeolitic material, thickly crowded with specks of magnetite, and sometimes with a green fibrous border, may represent olivine.

Matrix an extermely fine intergrowth of augite and felspar. Augite in light green granules, generally .01 millimetres and less in diameter. Felspars in laths, and magnetite very abundant. The relative proportion of the minerals in the matrix varies greatly; sometimes the felspar is predominant; at other times the augite and magnetite almost exclude the felspar.

No interstitial glass in the matrix.

Amygdaloidal blebs of glass represented by silica, probably by replacement; contain large idiomorphic crystals of bright leek-green augite, long felspar laths, and long minute needles of göthite; sometimes also larger lumps of iron ore, warm brown, and transparent on the edges. Indeterminate needles of a highly refractive mineral traverse the quartz. Interior of the larger blebs is again often hollow, and filled in with fibrous zeolites and calcite. The glass of the blebs is occasionally in its original condition when it is of a cloudy brown colour, and fine fibrous brown crystallites radiate from the edges of the felspars. Small crystals of magnetite form a border to the whole cavity.

Augite in the glass is sometimes changed to a blue-green to grass-green chlorite.

Slide No. 951
Class E

Agglomerate from the York volcano, along the cutting for the new road to Ongeluk's Nek.

A decomposed, greenish grey rock, with slate-coloured stony patches. A great quantity of irregular spaces, filled in with white radiating zeolites.

Under the Microscope:—

A few rare phenocrysts and hollow crystals of felspar, altered, lying in a matrix of brown glass, with feathery growths sometimes so far advanced that under a high power they can be resolved into frayed laths of felspar and granules of augite.

Blow-holes filled in with green zeolites.

Included fragments of true tuff, consisting of a greenish matrix, in which lie grains of quartz, felspar, ophitic grains of augite and felspar, augite alone, brown and transparent or cloudy.

Slide No. 953
Class

Horse-shoe dyke, Upsala.

A dense, greenish black rock, with an occasional dull cleavage face. Weathers with a brown crust.

Under the Microscope:—

A glass with feathery devitrifications, sometimes advanced to the condition of laths of felspar; a little magnetite.

The whole altered to calcite, with a little quartz and zeolites in the matrix.

Slide No. 954
Class G

Dolerite dyke in Red Beds, Otterburn, near the Little Umzimvubu River.

A dense black crystalline rock, with white felspars showing bright cleavage faces. General appearance dull, as if the rock had undergone much alteration.

Under the Microscope:—

Independent growth of felspar and augite, sometimes pegmatitic.

Felspar in twinned laths, with irregular boundaries.

Single long twins, or without twinning altogether, or with this developing and exhibiting shadowy lamellation.

Augite in irregular small grains, sometimes showing twinning along the orthopinacoid, but more often two individuals are intergrown along this plane, the interpenetration being hackly. The augite crystals that project into the green glass have an alteration to green, reedy hornblende, with very slight pleochroism, double refraction the same as the augite, and the two under crossed Nicols can not be distinguished.

Brown mica occurs in the glass, very pleochroic, brown to colourless.

Magnetite in large hollow octahedra, enclosing colourless glass, sometimes also augite.

Olivine represented by serpentine.

A certain amount of green granular glass, usually aggregated in patches, and not interstitial.

Slide No. 956
Class

Dyke in blue shales of the Molteno Series on banks of the Little Umzimvubu River, opposite N'Kadi.

A grey, compact rock, very similar in appearance to a limestone. Bright cleavage faces of calcite, and oval patches of a dark, slate-like rock.

Under the Microscope:—

Phenocrysts of felspar usually in the form of stout crystals, sometimes also in long laths, consisting of a single albite twin. Perhaps augite and olivine.

Matrix a fine granular mass, in which octahedra of iron ore are plentifully scattered.

The whole rock is intensely altered, and the minerals are now represented by pseudomorphs of calcite principally, also quartz and chlorite.

Slide No. 957
Class E

Sheet on the eastern bank of the Little Umzimvubu River, opposite N'Kadi.

A dense black rock, microcrystalline, with an oily lustre.

Under the Microscope:—

Large phenocrystal aggregates of felspar, zoned, but generally without lamellar twinning, or with shadowy lamellation. The constituent crystals are somewhat granular in outline.

There is no certain indication of porphyritic augite.

Olivine changed to serpentine and calcite, or to a light-green fibrous mass, with iron-ore secreted along the original cracks

Matrix consists of felspar laths and augite of a light ruddy colour, tending to form radiating groups. Augite in part lath-shaped, like the felspar, with orthopinacoidal twinning, otherwise in small granules.

There is a small amount of grey interstitial glass, with minute flecks of iron-ore.

Slide No. 958
Class B

Dyke through Pitso Beacon, western part of Matatiele Division. A tabular bit, 1 inch thick, between joints.

A compact, greenish grey rock, resembling a sandstone. Minute bright laths of felspar, also bright rounded specks.

Under the Microscope:—

A very fine-grained granular matrix of felspar and green augite, in which lie embedded small phenocrysts of augite. A very little olivine, with serpentine alteration, the augite sometimes also with a green chlorite alteration. Magnetite in small irregular bits.

Augite phenocrysts of the light ruddy variety, seldom with prismatic cleavage, which, however, is sometimes faintly visible under and between the coarse cracks that traverse the crystals. These cracks are sometimes conchoidal, and generally do not seem to be parallel to any definite face. The augite of the matrix is of the green variety, and not so previous to the felspar as in many of the rocks of this class. The granules are .1 millimetres and upwards in diameter.

Felspar in well-shaped, stout laths, .02 millimetres in average breadth.

Very frequent pegmatitic intergrowths of the felspar and augite arranged radially in large spherulitic masses. The augite is then equally lath-shaped, and the orthopinacoidal twinning makes it very similar in appearance to an albite twin of felspar. Magnetite is often arranged alongside the other minerals in these radial groups, and is in the form of long fibres.

Small granules and larger grains of olivine, previous to the minerals of the ground mass. A little alteration to serpentine.

Glass is only seen enclosed in some of the felspars.

Slide No. 959
Class B

Melaphyre from under the crest of the Drakensberg, on Zureka.

A dull, greenish black, flinty rock, with minute bright specks and small rounded amygdules, filled in with fibrous zeolites.

Under the Microscope:—

Felspar in porphyritic crystals, often in aggregates; frequently without lamellar twinning, and then with small intergrowths along the pericline axis. Lamellar twinning shadowy and indefinite. Felspar also in thin laths, formed of a single albite twin. Hollow forms, in which the greater part is inclusion, usually central, and consisting of microcrystalline matrix.

The phenocrysts are rounded and corroded, though in some the crystal faces and twinning remain to indicate the nature of the mineral. Inclusions in the larger, well-formed felspars are of brown granular glass.

Augite, and with it, perhaps, olivine, represented by small lumps of green alteration material and calcite.

Matrix a fine granular intergrowth of light green augite and felspar. Augite with strong relief seldom over .01 millimetres, more often a quarter of this size in section. Felspar laths average .02 by .005 millimetres. Interstitial glass certainly absent in some parts of the slide, but a greenish chlorite and calcite mixture, either altered glass or an infiltration product, is seen in other parts between the constituents of the matrix.

Small rounded blow-holes, filled in with an isotropic material, faintly red-brown; these have often radiating groups of needles growing out from the sides. The larger blow-holes with calcite in the centre.

Diabase, Drakensberg, Zureka.

Slide No. 960 A dull grey rock, somewhat greenish, with
Class **A** white felspars. A good deal of calcite. Small irregular cavities. filled in with opal and calcite.

Under the Microscope:—

Composed largely of ophitic lumps of augite and felspar laths, which have grown up independently. An earlier porphyritic felspar is present in large crystals, without twin lamellation, but strong zoning, corroded, and rounded. A later generation of stout felspar laths, averaging .24 x .1 millimetres, with repeated twin lamellation, usually in single laths, but also in clusters formed by lateral accretion.

Large patches of green and white alteration products, with calcite, may represent original olivine. Alteration of the felspars begins from the interior, leaving in most cases the outer edge fresh.

Augite of the ophitic grains entirely changed to chlorite.

There is a fair quantity of interstitial glass, of a greyish colour, with minute flecks of iron ore. The latter also occurs in long rods and grains.

Rock from the crest of the Drakensberg,
Slide No. 961 under the beacon Zureka, south side.
Class **B** A dull, greenish black rock, flinty, with minute bright specks, and many small rounded amygdules, filled with white zeolites. Also irregular amygdules,

drawn out, and filled with hackly quartz, dark green opal, and fibrous zeolites. Cracks filled with opal and quartz.

Under the Microscope:—

Felspar and augite phenocrysts, lying in a very fine matrix of felspar and green augite. Small rounded amygdaloidal cavities.

Felspar usually in stout prisms, often with large enclosures of glass in the centre. Large aggregations of laths. Extinction angle on the clinopinacoid over 30°, indicating a basic labradorite. Zoning in the untwinned individuals, also shadowy lamellation.

Augite changed to chlorite and calcite; occurs in lumps intergrown ophitically with the finer felspar laths.

Olivine in largish lumps, very much altered, with much calcite.

Matrix consisting of an extremely fine-grained mass of green augite and felspar, averaging respectively .01 and .03 by .005 millimetres. The augite, however, near the patches of glass becomes quite large.

Magnetite in small quantity.

Fresh interstitial glass, with alterations to a green mixture of chlorite and calcite.

Rounded vesicles filled with a yellow isotropic substance glassy, or with radiating fibres.

Slide No. 872 — Red bed between the lavas, top of the Drakensberg, on Eyrie.

Class H — Large and small grains of quartz, some clear, others full of inclusions; mostly irregular in shape and splintery.

Under the Microscope:—

Plagioclase and microcline, not very much altered.

Zircon in grains, fairly large and showing well the shell-like zonal structure.

A little brown mica.

A large quantity of fragments of glass, some grey and cloudy, others full of black specks. Others, again, with deep red transparent alteration products. The larger fragments have felspar laths imbedded in a microcrystalline base, and include also quartz grains that have evidently been picked up from the general sandstone débris.

Matrix in fair quantity, represented now by calcite.

Slide No. 873 — Siliceous rock interbedded in lava, top of Drakensberg, on Eyrie.

Class H — Under the Microscope:—

Quartz grains, and in less quantity, felspar, both orthoclase, and microcline; the former in untwinned cloudy grains, the latter fresh and showing the characteristic cross-hatching.

Zircon in grains, some quite large, with inclusions, which look like rutile, along the central axis of the crystals. Iron ore.

Fragments of shale, chloritized rock, and cloudy glass.

Matrix cloudy and colourless, with large quantity of calcite and chlorite forming irregular patches.

Slide No. 875 Volcanic breccia, neck on the farm N'Quatsha.
Class H Under the Microscope:—

Angular quartz grains, packed closely together, with a little red, dusty granular cement, in which there are minute shreds of white mica.

Quartz for the most part clear, with no signs of strain; edges seldom sharp, but corroded by the matrix. Some grains with a great deal of dusty inclusions, and rarely black, hair-like forms, presumably rutile.

A few angular fragments of microcline, quite fresh, but the other felspars are clouded with alteration products.

Small grains of zircon, rutile, white mica, chlorite, colourless garnet, and iron ore (haematite).

Epidote in considerable quantities, in small, yellowish, cloudy granules.

There are also small fragments of slate and sandstone, with secondary mica; also fine-grained basalt, consisting of laths of plagioclase and augite.

Slide No. 877 Included fragment in volcanic neck, filled with agglomerate, on the farm N'Quatsha.
Class H Rounded, sub-angular, or corroded fragments of quartz, with other minerals and rocks, set in a base composed of calcite.

Under the Microscope:—

Quartz, usually with inclusions, mostly dusty and too minute to recognise, but larger ones occur, which can be assigned to zircon and rutile occurring in small columns and in very thin hair-like threads. The dusty inclusions are often so aggregated in lines as to give the quartz grains the appearance of being fibrous. Under crossed Nicols, the quartz grains have wavy extinction, indicating strain.

Other minerals include fibrous chlorite, with calcite; calcite representing, perhaps, altered felspar; brilliant white mica, sericite; dark brown rutile; zircon; almost colourless garnet; and odd bits of fibrous minerals of indeterminate nature.

Rock fragments consist of sandstone, with much chlorite and epidote, and clay rocks altered to a felted mass of mica flakes.

Slide No. 895
Class H

Cave Sandstone from N'Quatsha's Nek road. A creamy white, chalk-like rock.

Under the Microscope:—

Quartz grains in large quantity, mostly with angular contours or with only one side rounded; almost always with trains of dusty inclusions. Large inclusions of rutile.

Felspar with cloudy alteration products, though the microclines are fresh. Untwinned grains, presumably orthoclase; others, plagioclase, with lamellar twinning, showing evidence of strain, for the lamellae are at slightly different angles in different parts of a grain; often, too, the lamellae are so close together as to give the grain the appearance of being fibrous.

Small columns of zircon included in some of the felspars.

Grains of zircon and rutile, and shreds of white mica, sericite.

A little brown hornblende and tourmaline, blue or brown.

No matrix, but the edges of the grains have developed a small amount of felted fibres of some micaceous mineral, to which is due the white colour of the rock as a whole.

Slide No. 963
Class

Green rock from the supposed volcano on top of the Drakensberg, on Zureka.

Under the Microscope:—

A granular green matrix, with a great number of felspar laths and aggregates of these laths; stouter crystals changed to calcite and green radiating zeolites, while the laths are unaltered. The whole of this part shows, by the disposition of the crystals, strong evidence of flow.

On either side of the green rock there is sandstone, one side being separated by a black line, which follows the irregularities of the grains in the sandstone; the other without this demarcation.

The sandstone consists of angular and sub-angular grains of quartz, with a little plagioclase felspar. Patches of a green material and of brown glass. Calcite occurs between the grains

REPORT

ON

A SURVEY OF PARTS

OF THE

BEAUFORT WEST, PRINCE ALBERT

AND

SUTHERLAND DIVISIONS.

BY

A. W. ROGERS AND E. H. L. SCHWARZ.

REPORT ON A SURVEY OF PARTS OF THE BEAUFORT WEST, PRINCE ALBERT, AND SUTHERLAND DIVISIONS.

The country described in this report includes the western part of Beaufort West, the western part of Prince Albert, and the south-eastern part of Sutherland; in the local nomenclature this tract contains the western end of the Gouph, the whole of the Mordenaar's Karroo, and part of the Klein Roggeveld.

The portion of the Gouph we are concerned with is that drained by the Dwyka River, which rises on the escarpment of the Nieuweveld; it is an arid, barren-looking country, lying between 1,700 and 3,000 feet above sea-level. To the north-west it is bounded by the Nieuweveld escarpment, which rises some 3,000 feet above the country at its foot; on the west by the range called the Mountains of the Gouph and Kouw's Berg.

The Mordenaar's Karroo is a very similar country to the Gouph, and occupies the greater part of the drainage basin of the Buffel's River north of the Zwartebergen, but that portion of the basin near the Tanqua watershed differs from the Mordenaar's Karroo very markedly in vegetation, and is known as the Klein Roggeveld. The Klein Roggeveld receives regular winter rains, which do not fall in the Mordenaar's Karroo or the Gouph. Both the Buffel's and Dwyka Rivers, as well as their tributaries, are practically dry throughout the greater part of the year, and water only runs in them after thunderstorms. Their beds are usually deeply buried in sand and fine gravel, through which the water from the numerous springs found along their courses filters slowly, so that it can be easily obtained by trenching. It is in this way that many of the farms along these rivers are supplied with water for irrigating the rich alluvial ground on the river banks; in other cases the spot where the water issues from the rock is found, opened up, and cleaned, so that a larger supply of water is obtained than was at first available. The springs issue from joints and bedding planes in the rocks, as none of these are sufficiently porous to allow water to percolate through them; in all cases the water seems to flow along narrow cracks.

The shape of the hills in the Gouph and the Mordenaar's Karroo is characteristic of a country where there is little vegetation; differences in lithological character make themselves very obvious on the surface. Beds of hard sandstone form cliffs on the hill sides, and the intervening shales and mudstones give rise to steep slopes, covered with small unweathered fragments of themselves, and larger, usually more weathered, bits of the sandstone above. It is a curious fact that the sandstone beds are nearly always more weathered than the shales; the explanation is that the sandstones are in general more porous, and at the same time, owing to their greater resistance to the denuding agents, a given surface is longer exposed than a given surface of the mudstones or shales. The thick sheets of dolerite which are frequently met with in the country near the Nieuweveld are even more resistant than the sandstones, and the escarpment of the Nieuweveld owes its abruptness to the thick dolerite sheets which protect the underlying rocks.

The chief agent of weathering in these districts is undoubtedly the alternation of high and low temperatures; the rocks are heated by the direct rays of the sun to a very considerable degree, and towards night, or during a thunderstorm, the temperature falls rapidly. This process is always going on, and causes the shales and mudstones to break up into angular fragments of small size, probably the fragments are eventually reduced by this means to so small a size that they can be blown away by the wind; the sandstones and dolerite are not affected so much by change of temperature as the shales and mudstones, but they also are broken up in this way. The heavy thunderstorms are very important agents in altering the surface of the ground thus prepared for their work by the physical disintegration of the rocks. There is an interesting feature in the steep-sided kloofs under the Nieuweveld which may be mentioned here. These valleys usually contain a great thickness of coarse gravelly breccia, through which the present stream beds are cut, often not deeply enough at some points to expose the solid rock below the breccia. The breccia is made up of angular and subangular fragments of the harder rocks of the surrounding hills, with remarkably little sand or mud between the fragments. There can be no doubt that the breccia is due to there being a greater supply of rock fragments than the stream can deal with; the stream itself is supplied with water charged with sand and silt from the hillsides, but there is not enough water to carry away the large fragments of rock, which accumulate and form the breccia. In a more moist locality, such as the Klein Roggeveld, the rocks are better protected from sudden changes of temperature by vegetation, and, therefore, chemical weathering and the production of soil go on more generally than in the drier districts, giving rise to more rounded surfaces, on which differences of structure in the underlying rocks are much less obvious than in the latter. The coarse breccia is not seen in the kloofs of the Klein Roggeveld, and even below the Komsberg escarpment, which receives more rain than the Nieuweveld, but is really the western continuation of the same escarpment, the breccias are less noticeable and thinner than in the valleys below the Nieuweveld. In some cases the matrix of the breccia is a white tufaceous limestone; this limestone, which is identical in character with the thick and thin layers of surface limestone found in many places in the district, is no doubt in part derived from the dolerites by weathering, but the sedimentary rocks must also be a source of the carbonate of lime. In the calcareous breccias, the carbonate of lime is deposited by percolating water.

The wind is an important agent in the removal of sand and dust from one spot to another in the Gouph and the Mordenaar's Karroo, where the vegetation is very scanty. The sand is blown about from place to place, forming miniature dunes on the lee-side of bushes, but it accumulates on the low-lying flats which border the larger rivers in many parts of their courses. This concentration of the sand near the rivers is mainly due to the sand being carried there by water during or after a fall of rain; the general surface of the country is then washed more or less clean of mud and sand, and the angular fragments of rock derived from the beds immediately below are left with only a very small quantity of soil between them. The joints on the surface of both the sedimentary rocks and the dolerite are usually rather wide and deep in the Karroo, and they are filled up with soil; it is usually in this soil that the plants of the Gouph and Mordenaar's Karroo grow, and their roots make their way down along the joints for considerable distances underground. Any conditions, such as the overstocking of the farms, which tend to reduce very much the already slight protection the soil receives from the vegetation, must do great injury to a dry country like the Gouph, an injury which the veld may take many years to recover from. As one travels through the Great Karroo, one notices marked differences in the state of the veld on neighbouring farms, a farm on which the veld is in good condition adjoins one that is little better than a desert. During our work in the Gouph the farm Groot Fontein, under the Nieuweveld, and the Hoogeveld some way to the south, had quite a refreshing appearance compared with the surrounding country, which was due to the careful stocking of those areas. It is indeed easy to imagine that an exceptionally severe drought might convert some parts of the Gouph into a stony and sandy desert.

The ground near the rivers, which is composed of the fine sandy silt, appears to be extremely fertile when water can be led on it, and where care is taken that the salts, contained to some extent in all the waters of the Karroo, do not become concentrated in the soil. Near a natural drain, such as a river bed, or on gravelly soil, irrigated land does not become brak. Even on flat land, without satisfactory natural drainage, the salts which cause the brakness may be entirely got rid of by artificial drainage or by the use of lucerne. It is a common experience that the best cultivable ground in the Karroo is that part of an alluvial tract which lies upon a coarse, easily permeable gravel, and the reason is that the soil in such a situation is protected from the concentration of the salts in the water used for irrigating it by the natural drainage provided by the underlying gravel.

The rocks which take part in the formation of our district belong almost entirely to the Karroo System; the only portion of the district where the rocks of the Cape System appear at the surface is the extreme south between the Buffel's River, below Laingsburg, and the Klein Zwartberg. This southern extremity was described in the Report for 1897, Appendix III., but during the survey on which that report was based, we did not examine the valley of the Buffel's River between the poort through the Klein Zwartberg and the Leeuw Kloof Poort. This river, which drains the whole of the Mordenaar's Karroo, and receives below Laingsburg the water from some 40 miles of the northern slopes of the Klein Zwartberg, and from both north and south slopes of the Witteberg, passes through the Klein Zwartberg by a narrow but deep gorge, which has vertical or almost vertical walls in many parts; the entrance to this gorge is only some 30 yards wide, while the river bed above the gorge is frequently over 300 yards in width.

At the north end of the great poort the sandstones of the Table Mountain Series dip northwards, and are conformably overlain by the Bokkeveld Series; the actual junction of the two formations is not seen, for it is hidden under the deposits of the Buffel's River. The Table Mountain Series is not much contorted in this portion of the Zwartberg anticline, but the Bokkeveld Series composed, as further to the east*, of shales with thick bands of sandstone, shows remarkable folds in the fine sections exposed in the cliffs on either bank of the river on the farm Ruggens Kraal, below the drift on the Seven Weeks' Poort road.

The Bokkeveld dips under the Witteberg Series near the Seven Weeks' Poort road, and in the latter formation similar folds appear, but they are sharper and less frequent, and have more the character of monoclinal folds, which have the same effect upon the outcrops of the rocks concerned as that produced by normal faulting. The width of the area occupied by the Witteberg Series is about twice that of the Bokkeveld, for there is a syncline in the middle of the Witteberg Series which practically doubles its outcrop, and which brings in the lowest beds of the Dwyka Series as an outlier capping a hill east of the Buffel's River, on the farm Nooitgedacht. North of the syncline the Witteberg Series forms an anticline, of which the northern limb dips at an angle of 80° below the Dwyka Series.

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* A detailed section of the Bokkeveld Series north of the Gamka Poort was published in the Report of the Geological Commission for 1899, pp. 33-49.

The classification of the rocks belonging to the Karroo System, which we shall adopt at present, is very similar to those of Feistmantel, Tate, Schenck, and Dunn . The chief difference is that we have separated the Dwyka Series from the Ecca; so far as the mapping is concerned, this separation is very easily effected, but it rests solely upon lithological differences between the two series.

The classification of the Karroo System used by us is the following:—

Karroo System.	Stormberg Sries	Volcanic Beds.
		Cave Sandstone.
		Red Beds.
		Molteno Beds.
	Beaufort Series	Zone of a highly specialized group of Theriodonts.
		Zone of *Dicynodon*.
		Zone of *Pareiasaurus*.
	Ecca Series ...	Shales and thin sandstones.
		Laingsburg Beds.
		Shales.
	Dwyka Series...	Upper Shales.
		Conglomerate.
		Lower Shales.

The scheme differs from that of Dunn (1887), in the separation of the Dwyka from the Ecca, instead of making the Dwyka the lowest subdivision of the "Lower Karroo." In Tate's classification a subdivision, called the "Koonap Beds," is placed between the Beaufort and Ecca; that author states that those beds occur in the Klein Roggeveld, a district made up of rocks, which we must regard as belonging to the Beaufort Series. Dunn places the Koonap Beds in the Ecca group along with the Kimberley Shales. For the present, therefore, this ill-defined group of Koonap Beds can be omitted.

The separation of the Ecca from the Beaufort Series is a difficult matter in the Gouph and Mordenaar's Karroo. There seems to be no unconformity in the Karroo System south of the Nieuweveld; the section near Aberdeen, drawn by the late Professor A. H. Green,* in which an unconformity is distinctly shown between the Ecca and the overlying rocks, has no counterpart in Beaufort West, Prince Albert, or Sutherland. We have traversed the country between the Nieuweveld and the southern border of the Great Karroo, along four different lines, and in a district where the rocks as a rule are admirably exposed; it is, therefore, unlikely that an unconformity such as that sketched by Professor Green could have escaped notice

Mr. Dunn has drawn sections through the Lower Karroo or Ecca, and Upper Karroo or Beaufort Beds, showing a marked unconformity between them in the Gouph.† It seems certain however, that the apparent unconformity caused by the sudden changes in the dip of the rocks has been mistaken for an actual unconformity.

Near Wagonmaker's Kraal, on the main railway line, there are good sections showing the occurrence of very sharply folded rocks; the beds sometimes dip vertically, and only a few score yards to the north these same beds have a very slight dip, and further north-east, towards Prince Albert Road Station, the rocks lie nearly horizontally. A very similar section is obtained between Thuyn Kraal and Prince Albert Road Station; yet another can be seen between Groot Fontein Station and Wilgebosch Fontein, to the north of the railway. In the Klein Roggeveld the lower part of the Karroo System, from the Dwyka Series upwards, is well exposed between Dwars in de Weg (Wilgehout Fontein) and Aanstoot; the rocks are much less folded here than further east in the Gouph, and any unconformity might be expected to be clearly shown, but there is a perfectly conformable succession. The same was the case with the section obtained along the Buffel's River, from the Dwyka Series north of Laïngsburg, to beds containing large bones near Koorn Plaats.

We have, therefore, come to the conclusion that in the Gouph, Mordenaar's Karroo, and Klein Roggeveld, there is no physical break between the Ecca and Beaufort Series, and that the distinction between them in that part of the Karroo is a purely palæontological and lithological one. The occurrence of the great fossil reptiles, *Pareiasaurus*, *Tapinocephalus*, and *Titanosuchus*, characterises the lower part of the Beaufort Series; neither these genera nor any allied forms have yet been found in the Ecca Series, which has so far yielded the remains of plants only. The small reptile, *Mesosaurus*, which was first found in the Kimberley Shales, has not been found south of Calvinia. In Calvinia* and Bushmanland it occurs in the white or black shales immediately above the Dwyka Conglomerate; these shales are considered to belong to the same group as the upper shales of the Dwyka Series in the south, with which they can for the present be classed.

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* Q. J. G. S., xliv., 1888, p. 261. Report on the Coals of Cape Colony, Cape Town, 1883, p. 25.

† In the "Report on a supposed extensive deposit of coal underlying the central Districts of the Colony," by Mr. E. J. Dunn, Cape Town, 1886, he corrects his former account of the relationship of the Upper Karroo Beds to the Lower (the Beaufort and Ecca series respectively), and says there is no unconformity between them, a view which has been confirmed by our observations.

Above the lowest, or *Pareiasaurus*, zone of the Beaufort Beds, comes the zone of *Dicynodon* and *Oudenodon*, but the zones higher than this cannot be well defined at present, and it is even doubtful whether *Dicynodon* does not occur together with *Pareiasaurus*. In Professor Seeley's account of the reptilian zones of the Karroo rocks,† the lowest (with the exception of the beds containing *Mesosaurus*) is said to be that of *Pristerodon* and *Oudenodon*, which occur at East London; but from a general knowledge of the geology of the country between Kei Road and the Komgha River, and from the fact that the strike of the Witteberg and Dwyka Series between Grahamstown and Port Alfred is east-south-east, it seems improbable that the East London rocks belong to the lowest part of the Beaufort Series. It is much more likely that they are above the *Pareiasaurus* zone, and are on the horizon of the *Dicynodon* zone of the Nieuweveld escarpment and Fort Beaufort, in which *Oudenodon* usually occurs. *Oudenodon* has not been found below *Pareiasaurus* in the Gouph or Fort Beaufort districts.

It is unfortunate that the exact localities from which many of the reptilian remains from South Africa came are unknown; this remark applies especially to the great collection of these reptiles in the British Museum.‡ That the subdivision of the Karroo rocks by means of the reptiles can only be carried out to a very limited extent at present is partly due to this defect in the records of the localities from which so many specimens came. It is not sufficient for purposes of subdivision of a great thickness of rock into zones that a locality should be given as "Sneeuwberg Range," or "The Rhenosterberg," for the specimen may come from any part of a vertical thickness, possibly of 3,000 feet. There is every probability, though, that the Karroo System will be satisfactorily subdivided by means of its reptilian fossils when these are sufficiently collected and known.

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* Report of the Geological Commission for 1900, p. 47. The Rev. Mr. Neethling, of Nieuwoudtville, showed us a specimen of *Mesosaurus* from the southern part of Bushmanland.

† Phil. Trans: of the Roy. Soc. of London, Vol. 183 (1892), B, p. 312.

‡ Catalogue of the Fossil Reptilia, etc., Part iv., R. Lydekker, London, 1895.

The plants from the lower series of the Karroo System have not yet been collected and worked out sufficiently to afford a secure means of recognising the beds in which they occur; the genus *Glossopteris* certainly occurs throughout a great thickness of rock in the Ecca and the Beaufort Series, but the determination of species from different horizons has not yet been accomplished. There is a plant, belonging to one of the genera *Phyllotheca* or *Calamites*, which is found from the Lower Dwyka Shales up to the Beaufort Beds, but as yet these remains are of little use as zone fossils; in fact, it appears to be impossible[*] to separate the genera *Phyllotheca* and *Calamites* in the imperfect drifted specimens which have up to the present been found in Cape Colony, and it is uncertain whether the two genera are represented, or only one of them.

The Dwyka Series is well seen on the farms Leeuw Kloof Poort and Floris Kraal, and for many miles east and west of these farms. The series occupies a belt of country some three miles wide, to the north of Leeuw Kloof Poort, owing to repetition by folding; the axes of the folds trend east and west, parallel with the strike of the rocks in the Zwartebergen. There are two anticlinal folds north of Laingsburg, which bring the Dwyka Series to the surface; their axes are parallel to the strike of the Zwartebergen rocks, that is, practically east and west; the axes of the folds have an easterly dip, so that the outcrops of the Dwyka Series have a boat-shaped termination towards the east. The southern of these two folds causes the upper shales of the Dwyka Series to cross the river about a mile above Laingsburg, but the conglomerate barely reaches the right bank of the river. The northern of the two anticlines brings the Dwyka Series to the surface on Dwars in de Weg, in the Sutherland Division. Both these areas of the Dwyka Series, due to the anticlines, are continuous with the main Dwyka area north and north-west of Matjes Fontein.

The Series in this district is divided up into three groups of beds:—

Upper shales,	approximate	maximum	thickness ...	550 feet.
Conglomerate,	„	„	„ ...	1,000 feet.
Lower shales,	„	„	„ ...	700 feet.

At Leeuw Kloof Poort there is a thickness of 700 feet of shaly beds; the lower part of these beds is a greenish, sandy, micaceous shale, frequently showing false bedding; in the middle of this group of shales there is a bed of hard, black, argillaceous rock, about two feet in thickness; the upper part of the shale group is less micaceous than the lower. In the valley of the Witteberg's River these shales were found to contain *Phyllotheca* (or *Calamites*), and some obscure stems that have not been determined. When the first account of the country near Laingsburg was written, the group of shales below the Dwyka Conglomerate was placed in the same series as the latter, according to the arrangement adopted by Dunn, and the discovery of *Phyllotheca* (or *Calamites*), which occur in the Ecca Series, but which have not yet been found in the Witteberg Series, certainly strengthens this classification. Lithologically this shale group at the base of the Dwyka has a considerable resemblance to the shales of the Witteberg Series. The conglomerate is seen in many admirable sections on Leeuw Kloof Poort and Floris Kraal. Large boulders up to three feet in diameter, are fairly abundant in the middle of the conglomerate, but thicknesses of some 200 feet at the bottom and top of the conglomerate are characterised by the rarity of these blocks. Bedding-planes are found throughout the whole thickness of conglomerate, but in parts, the rock between any two bedding-planes is some 20 feet thick; in other parts, the beds are under an inch thick. Striated boulders are found without difficulty, but do not appear to be so numerous as in the conglomerate in the north and north-west of the Colony. This may be at any rate partly accounted for by the greater hardness of the rock in the south, for the consequent result is that the boulders weather out less frequently, or are broken from the matrix in a more or less injured condition. Another cause of the less perfect state of the boulders obtained in the south than in the north is the greater development of the parallel joints in the former than in the latter. These joints are frequently so highly developed in the south that a pebble three inches long may have more than a dozen joints in it, and such a stone when struck will break along any one of these joints rather than come out of the matrix. The joints are entirely independent of any original planes in the pebble or boulder, such as those of bedding or foliation. They lie parallel to the strike of the rocks in the neighbourhood, but though they are often found to be parallel with the dip of the conglomerate, this is by no means always the case; in fact, they more nearly approach cleavage planes in their mode of occurrence than any other divisional planes in rocks, but they differ from cleavage planes in being less well-developed, in that a given pebble has a limited number of such planes in it, and not, as in the case of slate, a great number, which, though not unlimited, can hardly be determined. In the poort of the Geelbek's River, where there are good sections of the conglomerate, there was a boulder composed of a very basic rock that has not yet been identified with any rock known in place in the Colony, but which may easily be recognised when found in the future. In the hills north of Matjes Fontein, the conglomerate can be well seen; it contains numerous boulders of a rock composed of alternating thin layers of brown jasper and magnetite, which are much folded on a small scale. This rock is identical in character with many beds of the Griqua Town Series in the Doornbergen, near Prieska, and there is no doubt that the boulders were derived from the Doornbergen, or from the ranges made of the same Series further north. In some parts of the conglomerate of these hills, striated pebbles and boulders are rather more abundant than is usually the case in the south of the Colony.

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[*] "Fossil Plants," A. C. Seward, Vol. 1, p. 285

The beds overlying the conglomerate we have placed in former reports, with the latter, and the shales below, in the Dwyka Series; the upper shales are well exposed along the Buffel's River, above the Leeuw Kloof Poort. The upper limit of these shales, of which the " white band " of former reports is a part, is marked by a prominent band of white chert, from 12 to 18 inches thick. This chert band can be easily followed over considerable distances, and serves as a convenient horizon for mapping purposes. Above it lie shales and sandstones, of a different character from those which occur below, and they contain no beds of chert. In the absence of fossils from these shales, and also from a considerable thickness of the overlying rocks, it is of course impossible to place much confidence in the classification here adopted, which is essentially used for convenience of mapping, in order that the great thickness of the Karroo System may, to some extent, be broken up. At the same time the shales and sandstones (the Ecca Series), above the upper shales of the Dwyka, form a much more homogeneous group than they would were these included with them.*

An interesting section through the upper shales is exposed on a hillside near the Zout Kloof road, about a mile from Laingsburg. The section is through the south limb of the southern of the two anticlines mentioned on page 106, which bring the Dwyka Series to the surface. The white chert band and the underlying white weathering shales have been thrust over another portion of the same beds through a distance of about 150 yards, or even more. Another section near this one shows three smaller thrust-planes (reversed faults) very distinctly, owing to the faults passing through the white chert, the dislocated portions of which are exposed in the section.

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* See also Report of the Geological Commission for 1897, p. 67.

The Ecca Series rests conformably on the Upper Shales of the Dwyka Series. It consists of sandstones, shales, and mudstones. The lowest beds of the series are black, papery shales, followed by a thickness of about 1,000 feet of hard, grey sandstone, with which shales are interbedded. These sandstones are unlike any other rock in the lower part of the Karroo System; they are fine-grained, and are more quartzitic than the other sandstones, and weather with a thin yellowish-brown crust; from the thinness of the weathered crust it is obvious that they are closer in texture than most of the sandstones that occur on higher horizons. The latter are more deeply weathered, although the sandstones of the lower part of the Ecca Series form bold ridges, for the same reason that the higher sandstones give rise to krantzes and cap plateaux, on account of their resistance to the weather, so that both the lower and higher sandstones have been exposed during approximately equal periods. The sandstones form the hill near Laingsburg Station, and as they (together with the interbedded shales) are a fairly definite group of beds, differing at least lithologically from those above and below, it is convenient to give them a name—the Laingsburg Beds. These beds, with the underlying shales, form the parallel ranges of hills which extend from south of Blood River Station westwards, as far as the main road from Matjes Fontein to Sutherland, the western limit of our work in these rocks.

Very good sections through the Laingsburg Beds can be seen along the Geelbek's River, Zout River, and the Buffel's River both above and below Laingsburg. The Laingsburg Beds in the area with which we are dealing are folded considerably, and therefore occupy a belt of some miles in width, although at many outcrops their dip is as high as, or higher than, 45°.

Phyllotheca or *Calamites* occurs in the Laingsburg Beds, near the village of Laingsburg; on the farm Wilgehout Fontein (now called "Dwars in de Weg"), in the Division of Sutherland, a form of *Glossopteris* occurs, as well as the *Phyllotheca* or *Calmites*, and there was also found a leaf different from any that has been described from the Karroo System. A single specimen of *Glossopteris* was seen in the sandstone of these beds, between the railway station of Groot Fontein and the hotel.

Small pieces of silicified wood are frequently found in the area occupied by the Laingsburg Beds; they are weathered from their matrix, and are not often more than six inches long. The specimens we collected of this fossil wood were all lying upon the surface, but from their numbers and the position of several specimens, there can be no doubt but that they were derived from the Laingsburg Beds. Silicified wood occurs throughout the Karroo System, with the exception of the Dwyka Series, in which it has not yet been found; from the Ecca to the Stormberg Series very similar-looking specimens have been found, and so far as they have been examined under the microscope, it is probable that the trees from which the wood was derived were of the same kind, viz., coniferous. The "bordered pits," characteristic of some tissues in conifers, are recognisable in thin sections from certain of our specimens. Other parts of the trees have never been found in the Ecca Series.

The fossils mentioned above are the only ones known from the Laingsburg Beds.

A dark coloured, fine-grained argillaceous limestone occurs as nodules and irregular beds in the shales, both below and above the Laingsburg Beds, as well as in them; these lumps of limestone do not essentially differ from those that are found throughout the Beaufort Series embedded in the shales and mudstones. Occasionally also the nodular masses of limestone in the Beaufort Series reach such a size that they can be called lenticular beds. No organic remains have yet been found in the limestone of the Ecca Series, although, as will be described later, irregular masses of limestone are often found attached to, or embedding, the reptilian bones in the Beaufort Series.

The sandstones and shales of the Ecca and Beaufort Series frequently contain a small amount of carbonate of lime dispersed through their substance, and in most cases the limestone nodules appear to be local concretions of carbonate of lime, formed after the deposition of the rocks in which they occur. Some of the larger masses, which may measure 20 feet long in a section, and 2 or 3 feet thick, certainly have many characters in common with lenticular beds of ordinary sediments; but there are so many masses of limestone forming a transitional series between the small nodules and the lenticular beds that it is at least probable the two forms are in part of similar origin. A deposition of a sediment rich in organic matter probably served as a centre of attraction and deposition of carbonate of lime contained in the water, which saturated the rock after its formation.

The upper part of the Ecca Series consists of blue, grey, and purple shales and mudstones, with thin beds of sandstone. The sandstones are somewhat looser in texture than those of the Laingsburg Beds, and weather more deeply. Some of them have a very similar appearance to the rather coarse, "defining sandstones" of the Beaufort Series, which weather yellow; but they are not so thick as the characteristic sandstone bands of the latter. The shales and mudstones do not differ lithologically from those in the Beaufort Series, but are unlike the shales in the latter, in that they do not contain reptilian bones.

Below many of the sandstone beds in the Ecca and Beaufort Series there are thin layers of clay-pellet conglomerate. This is a rock consisting of what appear to have been lumps of mud, embedded in a matrix which differs slightly from the material of the lumps or pellets of mud. Their origin is easily explained on the supposition that portions of the muddy floor of the Karroo water basin were left high and dry for a short time, and that the previously deposited mud was hardened by exposure to the air; on the floor being again submerged, the hardened crust may have been broken up by currents, and the pellets derived from it deposited and buried by new sediment.

The formation of clay-pellet conglomerate can be observed at the present day in the Orange River. In places where a slight fall of the water level exposes a shelving bottom of mud, thousands of rounded lumps are sometimes seen lying on the surface. These lumps of mud are occasionally buried under silt brought down by the river, or one of its tributaries, and a true clay-pellet conglomerate is made. It of course frequently, or perhaps usually, happens that the pellets are broken up into their constituent grains before they are buried, and thus merely form fresh mud. There is no doubt that the pellets in the Orange River are formed by the breaking up of a hardened crust of mud by freshets. A similar formation of mud-pellets was noticed by us on the shores of the lagoons at the mouths of rivers in the Transkei and Pondoland.

Whether exposure to the air is necessary for the due hardening of the mud is a debatable point, but the solution of this question does not greatly affect the conclusion to be drawn from the frequence of clay-pellet conglomerates, that the beds were deposited in shallow water. Where any considerable section of the Ecca or Beaufort Series is available for examination, one can nearly always find evidence of false bedding, and in many cases distinct evidence that some previously deposited sediment was swept away and replaced by new material. It is quite possible that the clay-pellets may have been produced during this process. It is almost invariably found that the clay-pellet conglomerates underlie the sandstones, which means that after the deposition of the pellets, the current at that spot was able to carry off most of its finer-grained material, but had to deposit the sand grains.

The sandstones in the upper part of the Ecca Series are rather inconstant; when the outcrop of a particular bed is traced along a hillside, it is found to thin out within a few hundred yards, and usually a bed of a similar nature appears at a slightly higher or lower level.

The upper limit of the Ecca Series is difficult to define in the field in those parts where the reptilian remains have not been found. In the Gouph, where the bones of *Pareiasaurus* and other reptiles are rather abundant, the Ecca boundary is drawn just below the lowest beds containing them. The line thus obtained runs from Thuyn Kraal, south of Prince Albert Road, through Bad's Fontein, Jackal's Fontein, and Riet Fontein, to the valley of the Dwyka River, which it crosses on the farm Stink Fontein; from the Dwyka River, the line goes along the southern flank of the hills forming the divide between the Dwyka and Buffel's Rivers, on which Kouw's Berg stands; from Knoflock's Fontein, a farm which includes a part of the divide, the line runs northwards for a few miles, and then westwards, across the Buffel's River valley, near Cambro Hoek, in the Mordenaar's Karroo. It is impossible to define the line by the help of fossils in the western part of Mordenaar's Karroo and the Klein Roggeveld, on account of the absence of the bones characteristic of the Beaufort Series in the Gouph. For this reason we had to find some other guide in separating the two Series. In the Gouph, some of the thin sandstones ("intermediate sandstones") which occur in the lower part of the Beaufort Series weather in a peculiar way; they are rather compact, blue argillaceous sandstones, and weather with a very thin, bright red crust. These sandstones were not noticed in the rocks below those which contain the reptilian bones; so in the southern part of the Roggeveld, where sandstones similar to these occur, in a position which is on about the same horizon as the lowest outcrops containing reptilian remains in the Gouph, the upper limit of the Ecca Series has been drawn just below the lowest red-weathering sandstones. The red-weathering sandstones occur on the hill between Dwars in de Weg and Fortuin, which is the westermost part of the area occupied by this horizon that we mapped. In the broken country between Fortuin and Cambro Hoek, the line thus determined has a complicated form, owing to the deeply-cut river valleys and the high hills between them, along which the line between the two Series can be traced.

The Beaufort Series consists of sandstones, shales, and mudstones, resting conformably upon the Ecca Series in the Gouph, Mordenaar's Karroo, and Klein Roggeveld. The sandstones are of two kinds, a coarser and thicker one, beds of which in the 1896 Report* were called "defining sandstones," on account of their giving rise to rather extensive plateaux; and a finer grained kind, which forms thinner beds, "intermediate sandstones,"† and has a much less important effect upon the topography of the country. The intermediate sandstones where weathered are covered with a thin red crust, and the lowest of these was taken as the lower limit of the Beaufort Series in the absence of fossils. These sandstones extend across the Gouph to the Mordenaar's Karroo and Klein Roggeveld. In the Klein Roggeveld the rocks have a somewhat different appearance on the surface from that presented by them in the Mordenaar's Karroo and Gouph, on account of the moister climate in the former region; they resemble more closely, both in their outcrops and in the form of surface to which they give rise, the Idutywa Beds of the Transkei than their equivalents in the Gouph. There is no doubt, however, that the Klein Roggeveld rocks belong to the Beaufort Series, for the outcrops were followed along the high ground between the western tributaries of the Buffel's River into the Mordenaar's Karroo, where bones were found in them, and from the Mordenaar's Karroo into the hills forming the watershed between the Buffel's and the Dwyka Rivers, which we mapped from the neighbourhood of the Dwyka River during our journey through the Gouph. The difference between the appearances of the outcrops of these rocks in the Klein Roggeveld and the Gouph is due to the lighter colour of the weathered surfaces of the sandstones, and the yellow-brown weathered surfaces of the mudstones and shales. The "intermediate sandstones," which in the Gouph weather with a bright red surface, are usually dull brown on the outside in the Klein Roggeveld, owing to the hydration of the ferric oxide with which the exposed surfaces become covered. The "defining sandstones" usually present a light grey exterior in the Klein Roggeveld, owing to the more or less complete removal of the slight amount of hydrated oxides of iron, which tinge the same rocks in the Gouph and Mordenaar's Karroo with a brownish yellow colour.

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* Ann. Rep. of the Geol. Commission for 1896, Cape Town, 1897, p. 18.

A particular variety of sandstone, composed largely of grains of magnetite, is found in the Beaufort Series. The magnetite appears to have been deposited in the form it now has, and it is not due to the subsequent dehydration of other ores of iron. The magnetic sandstone was found in a hill near Knoflock's Fontein (Van der Byl's Kraal), in the Gouph, and is there sufficiently abundant to affect a compass needle held in the hand of a man standing on the hill; it was also seen on the farm Rheebok's Fontein (near Dam's Laagte), in the Klein Roggeveld, and at other places on the same horizon in that neighbourhood. It is unusual to find such a large amount of magnetite in a sedimentary rock; but on the Transkei coast, where the sand on the foreshore is derived in part from dolerites containing much magnetite, the grains of that mineral are concentrated in certain areas by the action of the waves.* The rarity of the mineral in sandstones is due to the fact that it usually becomes oxidised during or after the disintegration and weathering of the parent rock. There must have been some peculiar conditions in force during the formation of the magnetic sandstones of the Beaufort Series, perhaps similar circumstances to those which caused the preservation of the fresh felspar grains in the sandstones of the Karroo System generally. The further discussion of these questions must be left until we have a better knowledge of the characters and distribution of the sandstones throughout the system, and until detailed examinations of the rocks can be made in the laboratory.

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† *Loc cit.*, p. 18.

In the numerous extensive sections of the Beaufort Series to be seen in the great escarpment of the Komsberg and the Nieuweveld, the bands of sandstones, both "defining" and "intermediate," are well exposed. Each band has a horizontal extent of some 300 to 2,000 yards, or even more, but it is seen to thin out at either end, and another band of similar rock appears at a slightly higher or lower level. Without making a much more detailed survey than the topographical map at our disposal will bear, it is impossible to lay down the extent of each band of sandstone, and so to work out the history of its development and the direction of the current which deposited it.

In the Beaufort Series, as in the Ecca, there is abundant evidence from ripple marks, false-bedding, and the phenomena produced by "contemporaneous erosion and deposit," to show that the sediments were laid down in shallow water, and that in a given area periods of quiet deposition alternated with others, during which strong currents prevailed. As an example of contemporaneous erosion and deposit, we may draw attention to one of the many excellent sections exposed in the cliffs occasionally met with along the Dwyka River. On the left bank of that river near the mouth of the Steenkamp's River, a tributary of the Dwyka River from the west, there is a section showing two sandstone beds lying in hollows eroded in the surface of shales and mudstone. The two beds of sandstone are not directly connected in the plane of section, for a thin lenticular band of shale, of precisely the same nature as the shales on which the sandstones rest, lies between the upper surfaces of the latter and a thicker, overlying bed of sandstone; but at the two ends of the lenticular shale bed, the upper sandstone rests directly upon the two lower beds of similar rock. These sandstones are markedly false-bedded. The shales and mudstones of the Beaufort Series are very similar to those in the Ecca, but purple and reddish mudstones are rather more abundant in the former series.

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* See Annual Report of the Geological Commission for 1901, p.35.

The curious clay-pellet conglomerates, like those described from the Ecca, are found in the Beaufort Series, but those in the latter often contain rolled fragments of bone.

The nodules and thin beds of limestone in the mudstones and shales of the Beaufort Series sometimes contain small veins and irregularly shaped pipes filled with colourless and pink chalcedony, the origin of which is difficult to explain. In a few specimens, the abundance of the chalcedony and the circular form of the pipes in transverse sections, gives the limestone some resemblance to a fine grained amygdaloidal igneous rock. The chalcedony was certainly deposited after the formation of the enclosing limestone, but the origin of all the cavities which it fills is not obvious; the veins of chalcedony are not arranged in the way that the calcite is in septaria, but irregularly and not in the least symmetrically with reference to a central axis. In one specimen from Schiet Fontein, under the Komsberg escarpment, the chalcedony has evidently replaced a stem or root with small branches diverging from it at intervals, and it is not unlikely that all the pipe-like forms had a similar origin. In the neighbourhood of Van der Byl's Kraal, pink chalcedony fills up the cavities in the cellular tissue of bones of *Pareiasaurus* or other reptiles of large size. The pink chalcedony has not yet been found in the silicified wood which occurs both in the Ecca and Beaufort Series, but it appears to differ merely in colour from the form of silica which fills up the cells, and replaces the woody tissue, in the silicified wood.

These occurrences of the chalcedony evidently point to the agency of organic matter in causing the deposition of the silica, although the thin veins filled with the chalcedony show that it may occur independently of organic matter. The largest lumps of chalcedony which we found measured three inches in length, and one in diameter; these must have partially filled rather irregular cavities in the limestone, for there are frequently spaces in the middle of the lumps lined with botryoidal chalcedony.

Making allowance for the very different conditions of the enclosing limestones and of their formation, there is great analogy between the mode of occurrence of the chalcedony in the Karroo limestone and that of flint in chalk. Flint in chalk is usually intimately associated with organic remains, but also partially or wholly fills fissures in the enclosing chalk.

The Beaufort Series has long been famous on account of the numerous reptilian remains it has yielded. The lower part of the series contains *Pareiasaurus,* of which there are several species, *Tapinocephalus* and other genera, represented by fragmentary bones insufficient for determination. The remains of *Pareiasaurus* were found during the survey over a very wide area, extending from the neighbourhood of Prince Albert Road Station on the south to Groot Fontein under the Nieuweveld escarpment, and from Riet Fontein on the east, to Modder Fontein, in the Mordenaar's Karroo, on the west. In most cases the bones observed or collected were merely fragments, which were sufficient to prove the occurrence of *Pareiasaurus,* or in some cases probably other reptiles of large size. It was only in those spots that would obviously yield a good result that any considerable time was spent in excavating. On the farm Hoogeveld, lot A, near Van der Byl's Kraal, in the Gouph, we dug out a skeleton of *Pareiasaurus* which was embedded in mudstone, a rock which crumbles up rather readily on exposure to the air, especially when placed in the sun and occasionally wetted. This skeleton has been examined and described* by Dr. R. Broom, who considers it to be *Pareiasaurus serridens,* Owen. As in the case of many of the bones from the shales and mudstones of the Gouph, some of the bones of this skeleton were partly enveloped in limestone, in a way that suggests that the argillaceous matrix was locally enriched with carbonate of lime after the bones were buried.

At Groot Fontein, near the foot of the Nieuweveld escarpment, we obtained several bones belonging to one individual of a species of *Pareiasaurus.* Most of the bones were lying upon the surface, and had evidently been weathered out from the shales upon which they lay. On digging under the bones we obtained a few more, but the majority of the missing bones had either never been deposited at this spot, or had crumbled away from long exposure to the weather. Dr. Broom very kindly made the following notes upon this specimen:—

" The bones are those of a species of *Pareiasaurus,* and ap-
" parently belong to a single individual. As only two small
" fragments of the skull are preserved, the basi-occipital, and a
" small portion of the upper surface of the skull, it is impossible
" to say with certainty whether the species is new or not. The
" limb bones show that the individual was apparently smaller
" than the described specimens of *P. serridens* or *P. Baini,* and
" it is highly probable that the remains are those of a different
" species. *P. Russouwi,* which has been described from very
" fragmentary jaw remains, is evidently a small species, and it

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* The description of this specimen will shortly appear in the Palaeontogical volume of the Annals of the South African Museum.

" may be that the bones from Groot Fontein belong to this " species.

" The following remains have been recognised:—A number " of dorso-lumbar and sacral vertebræ. The vertebræ have the " bodies much more constricted than in *P. serridens*, and re- " semble more those of *P. bombidens*. Lower half of right " scapula, with portion of right clavicle, and the inter clavicle. " The scapula differs from that of *P. serridens* in having a " shorter acromion, and as a result, the distance from the acrom- " ion to the edge of the glenoid cavity is greater than in *P. ser-* " *ridens* (.104 m. as compared with .090 m.). The anterior part " of the glenoid cavity is much smaller in this animal than in " *P. serridens*.

" The other bones recognised are:—

" Lower end of left humerus; right ilium and portions of " pubis and ischium; left acetabulum; symphysis of the pubes " and ischia; left femur, resembling that of *P. serridens* rather than *P. Baini*, as regards shape and position of the trochanter " minor; it measures .340 m. Head of right femur, and lower " end; head of right tibia; head of left fibula, rather stouter " than in *P. serridens*."

On the farm Buffel's Vlei, in the south-western corner of Beaufort West, we obtained from a clay-pellet conglomerate below a bed of sandstone, an interclavicle, which is of sufficient interest to be recorded in this report.

Dr. Broom's description of this bone is as follows:—

" The inter-clavicle is unlike any inter-clavicle that has hitherto " been described. It is badly weathered, and the edges all " round, except at one point, have been broken off. It is a shield- " like bone about twice as long as broad, moderately convex " antero-posteriorly, and very convex transversely. It differs " markedly from the inter-clavicle of *Pareiasaurus* in that the " lateral expansions are here not at the anterior end of the bone, " but near the union of the anterior and middle thirds. The pos- " terior part of the bone is much broader than in *Pareiasaurus*. " As preserved, the bone measures in greatest length .220 m.; " in greatest breadth, .135 m. The average width of the pos- " terior part of the bone is .090 m. The described inter-clavicle " which most resembles it, is the inter-clavicle of a Pelycosaurian " (Embolophorus?) figured by Case.

" The inter-clavicle from its size and general characters is most " probably that of *Titanosuchus*."

On the farm Droogé Fontein, about seven miles south-east of Schoorsteen, on the Dwyka River, in the Prince Albert Division, we found a limb bone and five vertebræ, on which Dr. Broom made the following notes:—

"The limb bone is in two portions, which, though they do "not accurately fit, are almost certainly parts of the one bone, "with probably very little lost. It differs greatly from any of "the bones of *Pareiasaurus*, but resembles the bone figured as "the fibula of *Titanosuchus*. It is, however, appreciably smaller. "The vertebral centra differ markedly from those of *Pareiasaurus* in being much less deeply cupped. One centrum is that "of a dorsal vertebra, and shows that the articulation for the rib "is much higher than in *Pareiasaurus*. The other centra are "cervical.

"The remains are almost certainly those of a new fossil reptile—possibly allied to *Titanosuchus*."

At Knoflock's Fontein, near Van der Byl's Kraal, we were given by Mr. J. P. Snyman a large piece of pale green sandstone containing part of the snout of a *Titanosuchus*.* There is great doubt whether this specimen came from Knoflock's Fontein, as we were informed that a similar specimen had been carried to that farm from Klipbank's Fontein,† under the western part of the Nieuweveld. The greenish sandstone in which this fossil is embedded is very like the "intermediate sandstones" found throughout the Beaufort Series, and is no guide to the original locality of the specimen.

A bone determined by Dr. Broom to be the lower end of the left humerus of a Theriodont, possibly *Lycosaurus*, was found on the farm Paarde Bosch under the Komsberg escarpment. No specimens of *Dicynodon* have yet been discovered in this locality, and it is therefore not known whether the Theriodont bone comes from the *Dicynodon* Beds or that of *Pareiasaurus*. A large fragment of bone, probably belonging to *Pareiasaurus*, was noticed near Modder Fontein, in the Mordenaar's Karroo, on a horizon which is probably some 500 feet below that of the Theriodont bone. Up to the present no lithological differences have been noticed between the rocks belonging to the *Dicynodon* and *Pareiasaurus* Beds.

The plant remains found in the Beaufort Series belong to the same genera as those in the Ecca, or to closely allied forms. *Glossopteris* is widely distributed in the *Pareiasaurus* Beds. The coarse sandstones that occur on Ongeluk's Fontein in the Gouph contain large numbers of the leaves of *Glossopteris*, but the coarse texture of the rock is not favourable for the preservation of the leaves, which rarely show the venation, only the mid rib and faint indications of the venation are visible. Many specimens of the leaves were of considerable size, eight inches in length and two inches in width at the broadest part, but there is great variation in the leaves from one and the same bed of sandstone in this locality. There are three leaves connected with one stem or rhizome, but unfortunately this specimen could not be removed from the rock. Impressions of *Phyllotheca* or *Calamites* stems and other indetermined plants were found in the Ongeluk's Fontein sandstone, and also pieces of silicified wood. *Glossopteris* leaves, resembling those of Ongeluk's Fontein, were found on Doornbosch Fontein, between the Dwyka River and the Buffel's River watershed, and also near Houdenbek, on the Dwyka River. *Phyllotheca* or *Calamites* were also found on those two farms, and on Steenkamp's River. Silicified wood occurred on all these farms, and was also found on Riet Fontein, Prins Hoek, Groot Fontein, and Bulle Kraal, farms which are close under the western part of the Nieuweveld escarpment.

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* Dr. Broom has written a short description of this specimen, which will be published in the Palaeontological volume of the South African Museum Annals.

† Klipbank's Fontein is part of the farm Bulle Kraal, on the Divisional map of Beaufort West.

On the boundary between the farms De Hoop and Orange Fontein, there is a bed of dark purple shale containing great numbers of *Glossopteris* leaves, which evidently belong to a different species from those in the Ongeluk's Fontein sandstone. The coarse, thick sandstones, which cap the escarpment of the Komsberg above Schiet Fontein, contain numerous impressions of stem-like fragments of considerable size, but the short time we were able to devote to an examination of that rock between the edge of the escarpment and Tonteldoos Fontein was insufficient to allow us to collect well-preserved specimens. The impressions exposed on the surfaces of the massive sandstone beds were not good enough for identification.

The rocks of the Beaufort Series in the Gouph, Mordenaar's Karroo and Klein Roggeveld generally have a slight northerly or north-north-westerly dip, which is rarely as much as 5°, but they often lie flat, and occasional southerly dips are met with. The rocks are occasionally thrown into monoclinal folds, which have the effect of normal faults with southerly downthrows of from 20 to 50 feet. The folds run nearly east and west, but in some cases, especially in those folds which lie near the Komsberg escarpment, the direction is as much as 15° north of west. A good example of a monoclinal fold can be seen for some 30 miles under the Komsberg escarpment; it is exposed in the hills projecting southwards from the escarpment and traverses the farms Bushman's Hoek, Van Wyk's Kraal, Schiet Fontein, Botman's Hoek, Taaibosch Kraal, Sterboom Hoek, and Modder Fontein. This fold is rather longer than any other one of the same nature in the district surveyed. Only one of these monoclinal folds was observed with a northerly downthrow. The effect of the whole series of folds between the Komsberg and the southern limit of this type of fold in the Karroo has been to let down the rocks some 500 or 600 feet, near the southern limit, if the downthrows of all the folds are taken into consideration.

The lower part of the Beaufort Series in this district is not so conveniently exposed for measurement as the upper portion seen in the Nieuweveld escarpment. The sandstones, shales and mudstones of the part below the horizon of Groot Tafel Berg's Fontein are probably some 1,500 feet thick, and the general nature of the succession is much the same as in the section from Tafel Berg given below, with the addition of more clay-pellet conglomerates. A section through the upper part of the Beaufort Beds visible in the area we are concerned with, measured on the eastern side of the Tafel Berg, which is situated near the boundary between the Beaufort West and Fraserburg Divisions, west of the Thee Kloof road, gave the following result:—

Dolerite, forming top of the mountain	425 feet.
Hardened shale	5 „
Dolerite, an off-shoot from top sheet	20 „
Hardened shales and thin sandstones	180 „
Thick, platy sandstones	30 „
Shales, mudstones, and thin sandstones	202 „
Grey-weathering sandstone	8 „
Shales, mudstones, and thin sandstones	290 „
Yellow-weathering sandstone	10 „
Shales, green and purple	180 „
Blue sandstones	20 „
Grey, green, and purple shales	200 „
Yellow sandstones	30 „
Shales and thin sandstones	220 „
Yellow sandstone, with clay-pellet conglomerate below	10 „
Sandstone	20 „
Shales, with thin sandstones	220 „
Shales	10 „
Yellow sandstones	20 „
Shales, and thin sandstones	230 „
Yellow sandstone	10 „
Shales, with many limestone nodules	148 „
Sandstone	2 „
Shales,	50 „
Platy, red-weathering sandstones	10 „
Yellow and purple shales	90 „
Yellow sandstones	10 „
Green and purple shales	140 „
Sandstone	10 „
Purple shales	80 „
	2,880 feet.

This section, measured from the level of the farm-house on Groot Tafel Berg's Fontein, will serve as an example of the nature of the rocks and their succession. If a section had been measured on the western face of the mountain the positions of the bands of sandstone would in some cases have been different; and a section on the escarpment of the Nieuweveld at Matjes Kloof, some five miles east of Tafel Berg, bears only a general resemblance to the one given.

The greater part, if not the whole, of the beds detailed in the Tafel Berg section belong to the *Dicynodon* Beds, but it is possible that the upper part of the *Pareiasaurus* Beds are included in the lower part of the section. The horizon on which *Pareiasaurus* was found on Groot Fontein is some distance below the base of the section, for the beds, although very nearly flat, seem to have a general dip of one or two degrees towards the north-north-west in this neighbourhood. Some time after we had left Groot Tafel Berg's we met a farmer, Mr. Mocke, living at Riet Fontein, who had accompanied the late Mr. T. Bain when the latter made a large collection of skulls from a krantz on Hoedemaker's Kraal. This locality is doubtless the place where the specimens came from, which, in the British Museum Catalogue*, are said to have been obtained from "the Beaufort Beds on the flanks of the Nieuweveld range." The krantz on Hoedemaker's Kraal is on about the horizon of the upper 200 or 300 feet of sedimentary rock in the Tafel Berg section.

THE DOLERITES OF THE WESTERN NIEUWEVELD.

In the first Annual Report of the Geological Commission for 1896 there is a description of the dolerite sheets and dykes occurring on the edge of the eastern portion of the Nieuweveld, and in the country immediately below. In the map accompanying the Report the distribution of these was laid down with as great a degree of accuracy as the topography on the Divisional Map allowed. In the present Report we have to deal with the igneous intrusions to the west of those described in 1896.

The dolerite occurs in the angle between the Nieuweveld and the Gouph Mountains; on the north, on top of the mountains, there is the Fraserburg Division; and on the west, beyond the Dwyka River, there is the Sutherland Division. We confined our survey to the Beaufort Division, principally on account of the badness of the roads over the boundary, and as the dykes and sheets pass outside the area surveyed, the present account must necessarily be very incomplete. These dolerite intrusions are the most extended geological formation in the whole of South Africa, stretching with little variation in composition from sea to sea in the neighbourhood of latitude 32° S. Further accounts of them will be found in the Reports for 1899, Appendix III.; 1900, Appendices II., III., and IV.; and 1901, Appendices II. and III.

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* Catalogue of the Fossil Reptilia and Amphibia in the British Museum (Natural History), by R. Lydekker, Part iv., London, 1895. The localities of many specimens of the Dicynodontidae are given in these or similar words.

On the main road from Fraserburg Road to the village of Fraserburg, the first considerable hill is called Rooi Hoogte, from a great mass of dolerite which occurs here and weathers red. This is part of the inclined sheet called No. 4 in the 1896 Report. The dolerite forms an irregular sill, inclined at about 10° to the north. Along the banks of the Koekemoer's River, fine sections of the rock resting on sedimentary beds of the Beaufort Series may be seen. The dolerite is jointed, so that at places great vertical columns, from 80 to 100 feet high, have weathered out, and the underlying shales are seen to be baked and hardened at the contact. The upper limit, however, is not exposed in section, and it is therefore impossible to estimate the thickness of the sheet. The surface of the ground on top of the dolerite is thickly strewn with large rounded boulders of that rock, so that it is almost impossible to find a flat place to put one's foot down; in the interstices there are tufts of rich grass, a welcome change from the small bush of the Karroo immediately to the south, but the disadvantage of the ground is seen in the many lamed members of the flocks of sheep and goats that pasture on this veld.

The main road passes along the Koekemoer's River northwards, and the country beside it is described in the Reports for 1896, Appendix III., and 1900, Appendix III. On descending northward from Rooi Hoogte, there is a road turning sharply to the left, which leads into a basin shut in on all sides by dolerite; on the north, by the escarpment of the Nieuweveld, capped with the sheet called No. 3 in the 1896 Report; and on the south, by sheet No. 4. To the north of the road is seen a hill capped with dolerite, which in the 1896 Report was shown to be an offshoot of the sheet No. 4, and on the south is the Rooi Hoogte sheet, No. 4 proper. Passing the low hill, one enters an extensive flat country, sloping up to the escarpment of the Nieuweveld. On the summit of the mountains there are several detached caps of dolerite, from 400 to 600 feet thick; some of them are roughly columnar, and give to the mountain the appearance of being surmounted by a gigantic palisade. As far as we could make out, there are five caps, but it is very difficult to get an accurate idea of them, as there is no commanding position from which they can be surveyed. The streams have cut back so far into the edge of the escarpment that from below there appear to be many more detached caps than there actually are; it is only on ascending each separate mountain peak that one can see whether there is a bridge of igneous rock between it and the next. The westernmost cap overlooks the farms Mugge Fontein and Groot Tafel Berg's Fontein. The southern boundary of the dolerite here is cut into three peaks, but owing to the north-easterly dip of the sheet, streams that flow to the north-east, though their heads lie actually in the underlying shales, do not cut down through the dolerite for some considerable distance. The top of the cap forms an extensive plateau, covered with immense blocks of dolerite, and nourishes a vegetation which is particularly adapted for horses. From the most northern of the three peaks a very extensive view can be obtained, the village of Prince Albert on the south and the hills about Williston on the north being within sight, a distance of 145 miles; a signalling station between the two places was established here during the war.

To the north-west of this cap the ground is deeply cut into by the stream running down Thee Kloof, and here there are no further extensions of the sheet in this direction, at least, such as could be recognised from afar; but in the Fraserburg Division there may be detached dolerite sills which originally belonged to this one. To the west, there are the remarkable hills called Tafel Berg and Spits Kop, that form such conspicuous features in the landscape from the railway; they stand out clearly on the north-west of Prince Albert and Fraserburg Road Stations. Both are capped with dolerite, but that on Spits Kop is a mere remnant. Tafel Berg, however, has a considerable mass still remaining. It forms a vertical cliff to the south and east, but is more accessible on the west and north. On the east, there is an inclined rift running diagonally across the face of the wall of dolerite, and this forms a passage by means of which the top can be reached from this side. Here the main dolerite is seen to be underlain by baked shale, and a thin sheet, 20 feet thick, runs parallel to the main one, but separated by about 5 feet of shale. The dolerite of the main sheet is roughly columnar, each column being some 20 feet in diameter. At the south end the columns are continuous from top to bottom, and are 400 feet high by aneroid measurement; but the entire thickness of the sheet, measured from the highest point to the bottom of the main sheet, is 450 feet. Considering the amount that must have been removed by weathering, the sheet originally was probably thicker by at least a third, that is to say, 600 feet.

Along the Thee Kloof road, between the bottom of the pass and the farm on top, there are several dykes running a little north of east. The first lies along the boundary between the Beaufort West and Fraserburg Divisions. It is inclined about 30° to the north, and has baked and hardened the rocks on either side. It rises to within a couple of hundred feet of the height of the great dolerite sheet No. 3, and it is just possible that it may be an inclined portion of that sheet. About a mile north of this there is an exactly similar dyke; the Thee Kloof stream has cut down across both, but the hill-slopes, which otherwise would have afforded excellent sections, are covered with fallen blocks, which hide the rocks beneath. To the west, near Hoedemaker's Kraal, there is a similar stream coming from the north, which has cut through the southern of the two dykes, but has not yet made an impression on the northern. Except for these two "poorts," the dykes form a high barrier across the drainage, and the streams in their neighbourhood have to flow parallel to them.

West of Hoedemaker's Kraal there is a thick dyke of dolerite running north and south, and inclined 70° to the west. It rises on either side of the Hoedemaker's stream to the height of the plateau on top of the Nieuweveld, but on the west of it there is a large basin, cut into by the stream, exposing on the very steep hill-sides the peculiar light blue weathered shale of the higher Beaufort Beds. Two small sheets are exposed in the hollow, lying nearly horizontally. One is cut across by the north and south dyke, and a small dislocation is noticeable on either side of the great dyke, the sheet on the eastern side being slightly higher than that on the west. The west side of the hollow is bordered by hills rising above the general plateau, and behind them there is dolerite, but whether a portion of the Thee Kloof dyke, or an independent one, we were unable to make out; it lies in the Fraserburg Division.

Turning now to the Rooi Hoogte sheet: this was described in the 1896 Report as extending westwards from the furthest point reached in a series of ridges, with the scarped faces pointing south. This feature was found to be much more pronounced in the district recently surveyed than near Jackal's Fontein, where the work stopped in 1896.

The main sheet was found to divide near Rooi Hoogte into three portions. The highest, or most northerly one, soon disappeared on Paal Leegte. The middle portion rises as it goes westwards, and is exposed over an area of some 150 square miles along the course of the Tafel Berg's River. It rises to the plateau on which the Tafel Berg and Spits Kop rest, and continues westwards as a crowning sheet to the western portion of the Nieuweveld, as far back as Overse Fontein and Bank's Gaten, at the end of the district. The outcrop of the lowest, or most southerly portion, runs a little south of west, forming a dyke-like body, inclined some 30° to the north; but in the neighbourhood of the head waters of the Dwyka River it again splits up into several portions at different levels, and the outcrops of the various offshoots form an intricate series of loops around the hills on Bulle Kraal, Bank's Gaten, Riet Vlei, Drie Fontein, Rooi Berg, and Eland's Fontein. South of this last portion of sheet No. 4 there is no dolerite.

The most instructive section of this sheet is exposed along the Thee Kloof Road. One encounters it first on Kaffir's Kraal Hoek. Here there is a moderately thin sheet of dolerite, cutting across the horizontally bedded Beaufort Beds at an angle of 20°. This is the most southern portion, and it is seen extending to the east and to the west in the form of a low escarpment; north of this, to the east, there is a detached portion, apparently unconnected now with any portion of the sheet. To the west, there is a much larger detached mass of dolerite, forming a sheet capping a plateau, and rising to considerable heights in a series of small peaks. On following this particular portion westwards, it is seen to form the top of an extensive plateau on the farm Mechau's Request.*

The sheet has been extensively cut into by the streams on Mechau's Request, which have exposed the underlying beds along the sides of the channels; while on the west side, the sheet caps a small escarpment, facing the farms Groot Fontein and Prins Hoek.

Following the Thee Kloof Road northward, one enters a terribly rough country, formed by the weathering dolerite. The surface of the country is cumbered with great blocks of the rock, and the only flat place in sight is that of the road, which has been cut at enormous expense in the sheet along the sides of the rivers. To the east, the dolerite is seen to run out into several tongues, the dolerite in them being inclined gently to the north, with the south sides scarped. Three great tongues of this sort occur, besides the many-wrinkled one which runs east, past Jackal's Fontein to Rooi Hoogte. On the west, the sheet rises towards Tafel Berg, forming a slightly sloping plain of incredible roughness; rounded blocks of the size of cricket balls strew the spaces between the larger blocks of weathered dolerite, and the only vegetation is in the form of tufts of grass, and sparse, small bushes. Two outliers of shale and sandstone of the Beaufort Series rest on this plain of dolerite, one on Mugge Fontein and the other on Riet Fontein. At Mugge Fontein the road finally leaves the dolerite sheet, and the latter can be seen dipping under the horizontal strata along the banks of the Tafel Berg's River.

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*"Request" farms are those originally occupied by the Boers before the country was portioned out into farms. On occupying the ground, the settler sent in a request to the Landdrost for a title-deed, which was granted subject to a small perpetual quitrent.

Approaching the sheet from Groot Fontein on the east, one has the scarped hills on the boundary of Mechau's Request, which are capped by this sheet. Further north, one enters a narrow kloof, shut in by the two portions of the sheet, that on the west being considerably higher than the Mechau's Request portion. At Riet Fontein, one is right under the great krantz that the sheet forms on the top of the plateau. The farmer here pointed out the curious phenomenon of a patch of poisonous veld growing on a talus slope high up under the dolerite krantz. The poison veld owes its peculiar property in all probability to a certain bush which grows on it, but it is hard to see what conditions limit it to such small areas. The soil of this particular patch is derived from the wash from the dolerite, but at Dwars in de Weg, where another small patch occurs, and where we actually saw a number of fine, healthy oxen die from grazing but a short while on the veld, there is no dolerite within a radius of fifty miles. A legend has got abroad that the poison is due to the copper in the rocks on which the bushes grow, but this is not the case, nor would the small amount of copper thus assimilated by the plants be at all deleterious.

Following the dolerite sheet from Riet Fontein, it forms the crest of the plateau, which forms a promontory jutting out southwards into the farm Prins Hoek. The outcrop then passes north to the Fraserburg-Beaufort West boundary, and follows this all along on the top of the escarpment of the Nieuweveld, as far as Bank's Gaten.

SUPERFICIAL DEPOSITS.

The superficial deposits which come into the area dealt with in this report are of small importance compared with those south of the Langebergen. No patches of surface quartzite, such as occur widely in the coastal belt between the Cape Peninsula and Graham's Town, have yet been met with in the Great Karroo.

South of Laingsburg there is an area of very coarse gravel, containing boulders three feet in length, resting upon a terrace cut into the folded beds of the Witteberg and Dwyka Series. This gravel lies some 300 feet above the level of the Witteberg River and other local streams. In its mode of occurrence and position, it resembles the coarse gravels not unlike those which have at places a quartzitic matrix, and are found on the north side of the Langebergen. The high-level gravels found south of Laingsburg must have been deposited at a time when the level of the Buffel's River bed at the great poort through the Klein Zwartberg was some 300 feet higher than it is to-day; and it is probable that the terrace on which they lie was formed during a time of comparative inactivity of the downward erosive powers of the Buffel's River, for the rocks which have been cut flat are very resistant ones, and at the present time the grade of the tributaries of the Buffel's River is too great to allow of any appreciable wandering of the streams from their direct courses. It is very probable that a better knowledge of the widespread remnants of the gravel-covered plateaux south and north of the Langebergen, and of the gravel-covered terraces cut in the flanks of those ranges, will enable us to draw some definite conclusions as to the existence of a general period of downward activity of the rivers in the south of the Colony at a recent date, geologically speaking. The cause of such a period might be found in the approach to base-level of the main rivers of the country; and a subsequent rise in level of the land has renewed the downward cutting powers of the rivers.

Throughout the Great Karroo, deposits of white tufaceous limestone are often met with. They have already been mentioned on page 101, in connection with the breccias in the kloofs of the Nieuweveld escarpment. In the Gouph and Mordenaar's Karroo, the limestone is most frequently found in the rivers, for the reason that springs are more frequent along river beds than elsewhere, but there is much of the limestone in other places also. A deposit of the calcareous tufa is usually regarded by the farmers as a sign of the existence of a spring underneath, and an opening is made in the ground to allow the water to escape, frequently with a successful result. The calcareous matter is certainly deposited from spring water as a general rule, and this portion of the carbonate of lime is probably derived from the limestone, which we have described as rather abundant in the Beaufort and Ecca Series; as this carbonate of lime is in the form of calcite in the rocks, the water percolating through them merely dissolves it, and redeposits it on evaporation at the surface. Where dolerite occurs abundantly, it must be a great source of carbonate of lime, for oxide of calcium constitutes about 10 per cent. by weight of that rock, chiefly in combination with silica and alumina in the plagioclase felspars. On exposed surfaces of dolerite the plagioclase is dull white in colour, owing to its decomposition, another result of which is the solution of the lime, and its combination with the carbonic acid of the air or atmospheric water to form calcium carbonate; the carbonate of lime thus derived is held in solution until the water evaporates and deposits the lime. When one considers the enormous amount of dolerite which must formerly have existed between the present edge of the Nieuweveld escarpment and the position of the southernmost outcrop of the dolerite sheets which run from Beaufort West through Rooi Hoogte and Groot Fontein, to Bank's Gaten, it is obvious that the 1 per cent. of calcium oxide (capable of forming twice its weight of carbonate of lime) contained in it must have produced a very large quantity of the carbonate during the slow destruction of the dolerite. It must be admitted, however, that the lime-containing minerals of the dolerite are probably not entirely decomposed, but are partly carried down by the rivers in the form of more or less altered grains. During the survey, notes were made of the occurrence of boulders and pebbles of dolerite in the Dwyka River, below the southernmost dolerite sheets, and recognisable fragments of that rock were found some 20 miles below the outcrops. Below that point, no doubt a careful examination of the sand in the river would reveal grains of minerals derived from the dolerite; but it is very probable that the quantity of lime-containing minerals carried down unaltered is very minute in proportion to the weight of the decomposed minerals.

Reference has been made to the breccias in the steep kloofs of the Nieuweveld, and there is no need to deal further with these accumulations as part of the superficial deposits. In the lower parts of the Karroo, the alluvium deposited by the rivers is widespread, and forms by far the most valuable portions of the country; in some places the alluvium may be as much as 20 feet thick. It forms a light soil, remarkably fertile under irrigation.

CAPE OF GOOD HOPE.

DEPARTMENT OF AGRICULTURE.

ANNUAL REPORT
OF THE
GEOLOGICAL COMMISSION.
1903.

Presented to both Houses of Parliament by command of His Excellency the Governor.
1904.

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1903.

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Geological Commission of the Colony of the Cape of Good Hope

1903

MEMBERS OF THE COMMISSION.

The Hon. John Xavier Merriman, M.L.A.

Thomas Muir, C.M.G., LL.D., M.A., F.R.S., F.R.S.E.
Superintendent-General of Education.

Sir David Gill. K.C.B., LL.D., F.R.S., Hon. F.R.S.E.,
His Majesty's Astronomer at the Cape.

Thomas Stewart, M.I.C.E., F.G.S.

Charles Currey, Under Secretary for Agriculture.

Secretary—
Theodore Mackenzie.

SCIENTIFIC STAFF.

Director—
Arthur William Rogers, MA., F.G.S.

Geologists—
Ernest H. L. Schwarz, A.R.C.S., F.G.S.
Alex. L. du Toit, B.A., F.G.S.

Museum Assistant—
Miss M. Wilman.

Cape Town,
4th March, 1904.

The Hon.
The Secretary for Agriculture.

SIR,—I have the honour to forward herewith the report of the Geological Commission for the year 1903.

There is nothing special to record beyond the ordinary work of the survey which has steadily progressed.

Mr. Rogers, formerly the first Assistant Geologist, after acting as Director of the Survey in the place of Dr. Corstorphine, in which position he gave entire satisfaction, has been confirmed in the appointment formerly held by Dr. Corstorphine, and the Commission have every confidence that he will fill the position with advantage.

In consequence of the desire expressed that the work of the survey should be pushed on, the Commission assented to the appointment of an additional geologist. This post has been filled by a Colonist, Mr. A. L. du Toit, who, after a distinguished College career in South Africa, qualified in Europe both in theoretical and practical work. Mr. du Toit has taken up his field work and promises to be a valuable addition to the staff. Steps have been taken for the description and verification of various fossil remains discovered in the course of the survey ; the results, which are of considerable scientific value, have been by arrangement from time to time published in the "Annals of the South African Museum," of which they form a distinct volume.

I have the honour to be,
Sir,
Your obedient Servant,
JOHN X. MERRIMAN,
Chairman.

GEOLOGICAL SURVEY

OF THE

COLONY OF THE CAPE OF GOOD HOPE.

REPORT OF THE DIRECTOR FOR THE YEAR 1903.

During 1903 a greater area has been surveyed than in previous years owing to the addition of a third field geologist and to the fact that three working parties were in the field during the latter part of the year.

From March till the end of May I was accompanied by Mr. du Toit on a survey of parts of Sutherland, Calvinia, and Ceres; in June my services were lent to the South African College, which was then in difficulties owing to the unfortunate illness of Prof. Young; Mr. du Toit carried on the survey in the Karroo by himself during that month. This work completes the survey of the south-western portion of the Karroo. The most important results are the further light thrown upon the nature of the base of the Karroo Formation and the thinning of the Cape System north of Karroo Poort; the delimitation of the boundaries between the three lower members of the Karroo Formation in this area; the connection of the dolerite intrusions of the Roggeveld with those of the western Nieuweveld; and the examination of the large group of volcanic vents in Sutherland, which has yielded much information bearing on the history of vulcanism in the Colony.

Mr. Schwarz devoted the whole of his time in the field to mapping the Divisions of Prince Albert, Willowmore and Uniondale, which include large tracts of very rugged country where the usual difficulties incident to travelling in such a region were greatly increased by the drought. This work fills a decided gap in our knowledge of the southern mountainous belt, for the previous geological maps which include that part of the country give no idea of its complexity, and, so far as I am aware, no description of the geology has ever been written before. On the maps of the district at present available it would be impossible to lay down the details of its structure, but the main lines are brought out clearly in Mr. Schwarz's maps and description. The earth-movements that produced the intense folding in that district, as in other parts of the folded belt south of the Karroo hitherto surveyed, took place before the Uitenhage period, but the evidence now brought forward proves that disturbances of considerable importance affected the area after the deposition of the Uitenhage Beds, a conclusion that had been foreshadowed by previous work of the survey in the country south of the Langebergen. Mr. Schwarz's work has also added much to our information concerning the gravel-capped terraces which are so widely developed south of the Karroo. The latest part of the geological history of the Colony is to be learned from these terraces, but in the absence of contoured maps their study is a matter of very great difficulty.

From September to December I was engaged in surveying the west coast district from Piquetberg northwards to the Olifant's River, a country that proved rather uninteresting on account of the thick covering of sand which conceals the solid geology of the greater part of the district. The recognition of a group of rocks in the Verloren Valley intermediate in age between the Malmesbury Series and the Table Mountain Sandstone is of considerable interest, as it tends to confirm the view put forward in the Report for 1900 as to relationship of the Ibiquas Beds in Van Rhyn's Dorp to the Malmesbury Series, though in the absence of fossils the correlation of the distant outcrops must remain hypothetical. The general structure of this district may be explained by saying that it is covered by a sheet of slightly disturbed sandstone, belonging to the Table Mountain Series, flanking the folded belt west of the Karroo, and that at places denudation has laid bare the older and highly crumpled rocks lying below the sandstone. In the northern part of the area the hills and valleys are being obliterated by the deposition of sand derived from the mountains to the east, so that at many places the tops of the sandstone hills alone project above the sand.

Some three weeks in August and September were spent by Mr. du Toit in mapping the Cape Peninsula, but the work will not be published until he has completed it and has examined certain of the rocks in detail. An interesting point in this survey is the finding of intrusive dykes of dolerite in the Table Mountain Sandstone, which, together with the chemical and petrographical resemblances between those dykes and the Karroo intrusions, leaves little doubt that the Peninsula and the Karroo dolerites were closely connected in origin.

During the rest of the year Mr. du Toit worked on the Tembuland side of the Drakensberg, and partly filled in the gap between Mr. Dunn's map of 1878 and Mr. Schwarz's work of 1902. The coal horizons have been carefully followed up, and much information respecting them has been collected. The Red Beds and Cave Sandstone are thicker in this district than in other localities where they have been measured, but, as in the north-east of Matatiele, the Cave Sandstone is absent at places between the Red Beds and the lavas, owing to denudation which took place before the out-pouring of the lavas. Many volcanic pipes of the same nature as those described in the Report for 1902 were found near the great ridge of the Drakensbergen. A map of this district will be published after some of the surrounding country has been surveyed.

The work of describing and figuring the Cape fossils has made considerable progress during the past year. The following papers have been published :—(1) " Fossil Floras of Cape Colony," by A. C. Seward, F.R.S. Annals of the S.A. Museum Vol. IV Part I. pp. 1-122, with 14 plates and 8 text figures. (2) Six papers by Dr. R. Broom, "On an almost perfect skeleton of *Pareiasaurus serridens* Owen," " On the structure of the Shoulder Girdle in *Lystrosaurus*," " On evidence of a new species of *Titanosuchus* (*T. cloetei*)," "On the presence of a pair of Distinct Prevomers in *Titanosuchus*," "On some new primitive Theriodonts in the South African Museum," "On a New Reptile (*Proterosuchus fergusi*) from the Karoo Beds of Tarkastad, South Africa." These papers form Part II of Vol. IV of the Annals, and occupy pp. 123-164 with 5 plates and 2 text figures. The work on the Brachiopods and Mollusca of the Bokkeveld Beds by Mr. F. R. C. Reed was nearly finished at the end of the year, and since then one of the papers has been issued. Mr. P. Lake's Account of the Bokkeveld Trilobites is also finished but has not yet been published, and the same is the case with Mr. F. Chapman's description of the Foraminifera and Ostracoda from the Pondoland Cretaceous Beds. The papers dealing with the fossil plants and the Bokkeveld invertebrates will be of very great use in the immediate future.

The want of an index to the previously published Annual Reports has been very much felt, so it has been decided to compile an index to the Reports for the years 1896-1903, and to publish it, if possible, during the present year. In the future it is intended to add an index to each yearly volume.

The illustration of some of the geological descriptions in this Report by diagrams and photographs, and by more maps than usual will be found an improvement; we propose to make more use of illustrations in the future.

The following papers have been published by the members of the staff during the past year in the "Transactions of the South African Philosophical Society:"—"The Transkei Gap," by A. W. Rogers and E. H. L. Schwarz, "The Volcanoes of Griqualand East," by E. H. L. Schwarz, "The Geological History of the Gouritz River System," by A. W. Rogers, "An unrecognised Agent in the Deformation of Rocks," by E. H. L. Schwarz.

The thanks of the Commission are due to the donors of many papers and journals, which have in all cases been acknowledged soon after their arrival.

Dr. R. Broom has kindly determined several reptilian bones collected during the past year.

To Mr. J. Lewis, of the Government Analytical Laboratory, we owe a complete chemical analysis of the melilite-basalt of Spiegel River, which is printed in the report upon Sutherland, where allied rocks occur. Owing to the remarkably fresh state of this rock the analysis will be of more than local interest, for melilite-basalt is a very unusual, but at the same time interesting, type of igneous rock.

ARTHUR W. ROGERS.

GEOLOGICAL SURVEY OF PARTS
OF THE
DIVISIONS OF CERES, SUTHERLAND, AND CALVINIA.

BY

A. W. ROGERS

AND

A. L. DU TOIT.

GEOLOGICAL SURVEY OF PARTS OF THE DIVISIONS OF CERES, SUTHERLAND, AND CALVINIA.

By A. W. Rogers and A. L. du Toit.

The field work in the Western Karroo and Roggeveld occupied nearly four months and extended over parts of the Divisions of Ceres, Sutherland, Calvinia, and a few miles of the extreme north of Worcester. Although made up of portions of four fiscal Divisions, the area is continuous and of considerable extent, and connects districts surveyed in the years between 1896 and 1902. In Ceres and Calvinia the western limit of the area is the eastern slope of the Zwart Ruggens and a line drawn due north along the foot of that slope; the northern boundary in Calvinia is the edge of Hantam Berg, and the eastern limit passes from the Hantam south-east to Sutherland, thence to the western boundary of Beaufort West, down the watershed of the Klein Roggeveld to the Bonteberg range, and from there westwards to Karroo Poort and the Zwart Ruggens.

The chief physical feature in our district is the escarpment of the Roggeveld, which trends south-south-east from the valley of the Oorlog's Kloof River at the place where that river passes between the Hantam Berg and Kreit's Berg. The Hantam Berg is really an outlier of the Roggeveld, separated from the main area by the Oorlog's Kloof valley. The Roggeveld escarpment is cut back by several streams into precipitous kloofs, of which the principal examples, beginning from the north end, are the Keiskie Poort, the Uitkomst Poort, Roode Fontein Kloof, Bosch Kloof, the kloofs on Olyven Bosch, Klip Fontein, and Gannaga and the one at the head waters of the Rhenoster River.[*] Beyond the kloof of the Rhenoster River the escarpment is embayed by the smaller tributaries of the Tanqua, the most important of which, the Verlaten Kloof stream, has cut back its valley some nine miles. East of Verlaten Kloof the escarpment is called the Komsberg, and is described in the report on a former survey.[†]

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[*] This Rhenoster River is a tributary of the Tanqua, and must not be confused with the much more important river of the same name that flows northward from the neighbourhood of Sutherland village to join the Great Fish River above Tontelbosch Kolk.

[†] Geol. Com. Ann. Rep. for 1902, p. 119.

The country to the east and north of the Roggeveld-Komsberg escarpment has a very gradual slope to the north, although the surface is sufficiently diversified by ridges and table-shaped hills. A long group of ridges can be traced from the western end of the Nieuweveld near Bontberg to Sutherland, thence west-north-west to the Great Fish River at Koornland's Kloof; from the Great Fish River these hills run north-north-west to Middle Post, and into the Zwarte Bergen and Klip Fontein's Berg in Calvinia. These ridges are due to the presence of the intrusive dolerite, the outcrops of which have been cut into very complicated forms by denudation acting now on nearly horizontal sheets and now on inclined masses of the rock.

To the south of Komsberg the high and broad ridge known as the Klein Roggeveld extends to within twenty miles of the main line of railway at Matjes Fontein. Several wide tongues of high ground stretch westwards from the Klein Roggeveld into the Ceres and Tanqua Karroo.

To the west of the Roggeveld and Klein Roggeveld there is a tract of lower ground varying from twenty to thirty miles in width, and extending from Klip Rug Kop on the north to Karroo Poort in the south, a distance of about 100 miles; from Karroo Poort the low country is continued eastwards between the Matjes Fontein hills and the Klein Roggeveld, and is connected with the Great Karroo through Laingsburg. This low country lies between 1,100 feet (Eland's Vley) and 2,000 feet above the sea, and is known under the names of the Tanqua Karroo in the north, and the Ceres or Bokkeveld Karroo in its southern portion and, as a whole, it can be called the Western Karroo.

To the west of the Karroo rise the Zwart Ruggens, a bare and dry dip-slope of Witteberg Beds, continued round the south of the Ceres Karroo by the Bontebergen. The Tanqua Karroo is drained by the Tanqua and its tributaries; the main stream enters the Doorn River at Eland's Vley. Dry throughout the greater part of the year, it is only after rains that water can be freely obtained in the Western Karroo. Although seemingly more favourably situated for the occurrence of rain and springs than the Great Karroo, the Western Karroo appears to be a drier country than the Gouph, and springs are certainly fewer there than in the western part of the Gouph.

The Doorn River, fed by the rains that fall on the eastern slopes of the Cederbergen and in the Cold Bokkeveld, contains a great body of fresh water during eight months of the year. It leaves the Zwart Ruggens by a great gorge with almost vertical sides, and flows for some twelve miles along the western boundary of the Karroo, but unfortunately at so considerable a depth below the general surface of the Karroo that no attempts have yet been made on anything but the smallest scale to take

out the water and lead it over the adjoining ground. To a person who reaches the Doorn River after a long journey across the Karroo the sight of so much clear water is indeed welcome, but at the same time he is full of regret that use is not made of the immense volume of water that is now permitted to run straight to the Atlantic Ocean. The Doorn River receives tributaries from the southern part of the Western Karroo, which together form the Dwequa or Salt River (Groot River).

The sedimentary formations that come within our area include the uppermost part of the Witteberg Series, the whole of the Dwyka and Ecca, and the lower part of the Beaufort Series; in addition to these sedimentary rocks we have to deal with an important part of the dolerite intrusions of the interior of the Colony, and with an extremely interesting group of volcanic rocks occupying but a very small proportion of the whole district. Some gravel and alluvial deposits are of importance in the Tanqua Karroo.

Our district forms part of the edge and interior of the south-western corner of the interior basin of the Cape Colony. The southern boundary of the basin is due to folding, which has taken place subsequently to the deposition of the rocks occupying the interior, but the western boundary is not solely due to the same cause. In its southern portion the western limit is due to folding, but on tracing it northwards the Dwyka Series, the lowest number of the interior group, becomes less and less affected by folding, and at the same time is separated from the underlying beds by an unconformity that increases steadily in value towards the north, showing that the original western edge of the area of deposition of the Karroo formation was at a certain period not far from the present outcrop of the Dwyka.

The southern boundary-folds were produced by a force acting in a north and south direction, and the western ones by an east and west force. The two groups of folds meet in the neighbourhood of Karroo Poort, and a complicated structure is the result. The diagonal folds, directed approximately north-west and north-east, that occur over a considerable area, from the Cold Bokkeveld to the south-east limit of the Ceres Division, may be regarded as due to the conflict betwen the two sets of forces.* Outside our district, in the country between Ceres and Bredasdorp,† the resultant diagonal folds are much more marked than in the Karroo Poort region, and occur to the almost complete exclusion of others. The north-west folds are seen near Karroo Poort in the Drie Fontein Dwyka outlier, and in many minor flexures of a monoclinal nature that give the outcrops of

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* This type of structure is distinct from an arc, and has received the name of Schaarung in German or Rebroussement in French, but there is no English term to express the meaning.

† Ann. Rep. Geol. Com. for 1898, pp. 42–47.

The country to the east and north of the Roggeveld-Komsberg escarpment has a very gradual slope to the north, although the surface is sufficiently diversified by ridges and table-shaped hills. A long group of ridges can be traced from the western end of the Nieuweveld near Bontberg to Sutherland, thence west-north-west to the Great Fish River at Koornland's Kloof; from the Great Fish River these hills run north-north-west to Middle Post, and into the Zwarte Bergen and Klip Fontein's Berg in Calvinia. These ridges are due to the presence of the intrusive dolerite, the outcrops of which have been cut into very complicated forms by denudation acting now on nearly horizontal sheets and now on inclined masses of the rock.

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† Ann. Rep. Geol. Com. for 1898, pp. 42–47.

The north and south fold of the Zwart Ruggens is, broadly speaking, the eastern limb of a great anticline and brings the level of the top of the Witteberg group down through 3,000 feet, the height of the Cold Bokkeveld hills above the Karroo. The fold then flattens out, carrying the Witteberg Beds under the Karroo. Towards Karroo Poort the ZwartRuggens fold is frequently interrupted by small diagonal flexures, the effect of which in breaking up the regularity of dip of the Witteberg Beds can be well seen by travellers along the Calvinia road.

The east and west folds along the southern borders of the Karroo die out gradually, smaller and smaller folds being met with till the rocks become practically undisturbed over wide areas. These folds have a marked tendency to pitch eastwards, so that the anticlinal portion of the outcrop of any one stratum ends towards the east in a sharp boat-shaped curve, and the synclinal portions terminate in a similar but reversed fashion towards the west. The two largest anticlines of this nature are those that bring in the Dwyka Series between Drie Kop and the north of Zout Kloof, and a similar anticline that passes south of Zout Kloof and reaches the Buffel's River north of Laingsburg.

Although when we leave the folded region and enter the Karroo proper, the rocks are found to be much less disturbed, yet there is plenty of evidence that there was a considerable amount of movement in the Karroo area, and the general parallelism of the resulting structures with the east-west and the north-south folds of the Mountain belt points to their being due to the same sets of forces that produced the latter. There is a tendency in these Karroo structures to assume the form of monoclinal folds, with a sharp southerly dip, having almost the same effect on the rocks concerned as a normal fault.

The strata forming the Koedoe's Mountains, the Tanqua Valley, and the Klein Roggeveld, are traversed by a series of monoclinal folds, which occasionally displace the beds to a considerable extent, usually towards the south. On the western side of the mountains the folds run a little north of east, but they curve round until in the Tanqua basin they run a little south of east. At Matjes Fontein (near Olivier's Berg) one of these folds brings down a massive sandstone band capping the hills to the north almost to the bottom of the valley, a distance of over 450 feet. The beds have a dip of 45° in the monocline, and there is evidence of some faulting as well. Another fold occurs in the valley of the Ongeluk's River, near the farm Gat's River; the hills to the north of Gat's River are formed by the dip-slope, with an angle of 40°; the downthrow or vertical displacement is as much as 1,000 feet at one point. A prominent anticlinal fold, which in places is almost a monocline, is met with on the north side of the Muishond River, and is crossed by the road from Baken's River to Bantam's Fontein, which descends a dip-slope of about 30°.

Faults are not infrequent in the Tanqua region, especially near Olivier's Berg, and at several places the strata are tilted to a high degree, and even overturned. Small reversed faults are not uncommon, and the rocks are slickensided and traversed by veins of quartz. At Blaauw Heuvel, near the junction of the Hout Hoek and Tanqua Rivers, there is an interesting reversed fault trending about 10° north of east. The shales of the lower part of the Ecca Series are brought up against a massive pale blue sandstone belonging to the middle part of the same series; the beds near the fault-plane in Hout Hoek River are almost vertical, and form a great wall on the right bank. A short distance further up the Tanqua the Ecca Beds are folded and faulted both in an east and west, and to a smaller extent in a north and south direction.

It is interesting to note that it is only beyond the limit of these dislocations that the intrusions of dolerite become abundant. Within the area of considerable disturbance there have been found but three dykes, two of these occur on Elizabeth's Fontein and Frederick's Dal in the Clanwilliam Division, which lies outside our district, and the third is the north and south dyke on Beukes Fontein. Three dykes with a north-westerly trend have been found near the Tanqua River between Tuin Plaats (Vinke Kuil of the maps) and the Twee Fontein drift, but the sheets and dykes of the Roggeveld group are only strongly developed some distance north of the Tanqua.

THE WITTEBERG SERIES.

The Witteberg Beds that come into our district are the quartzites and micaceous shales of the Bontebergen, the Karroo Poort hills, and the Zwart Ruggens.

In the Bontebergen and Karroo Poort area the beds are much folded, but as a whole dip northwards under the Dwyka Series. The dips usually range up to 35°, but on the farm Melkbosch Kraal and Bruwell's Fontein the dips are higher and at places nearly vertical. That the folds do not die out at the base of the mountains, but affect the strata to the north also, is shown by the occurrence of three anticlinal inliers of Witteberg Beds in the midst of the Dwyka Series near Toverkop. One of these occurs two miles east of the Plat Fontein outspan, and is about a mile long; another lies half a mile south of Toverkop, and has a length of two miles. Each of these inliers is an anticlinal ridge rising abruptly above the general level of the ground. The third and smallest inlier is on the west side and at the foot of Toverkop.

The Zwart Ruggens extend from Quarrie Berg, north of Karroo Poort to the Doorn River beyond Eland's Vley, a distance of about 57 miles. The beds dip at moderate angles eastward under the Dwyka Series, and do not reappear at the surface. About eleven miles north of Eland's Vley, on Drie Kop, the Dwyka Series rests directly upon the Bokkeveld Beds, proving that the whole of the Witteberg Series had been removed from that spot and the country to the north, before the Dwyka Beds were deposited, or else that the Witteberg Beds were never deposited there. The latter view is untenable, for there is so far no evidence to support it; on the other hand, a careful inspection of the Witteberg-Dwyka boundary between Drie Kop and Blood River showed that higher and higher beds of the lower formation come in towards the south, till at De Vallei and Platte Klip the whole thickness of the Witteberg Series, as well as the lower Dwyka shales, is present, and there is apparently no change in the nature of the rocks which would point to a lack of material during deposition. The boundary itself is obscured throughout almost the whole of its length either by sand (northern part) or accumulations of ferruginous gravel, so that the very interesting question of the relation of the Dwyka Conglomerate to the Witteberg Beds north of the areas where the junction is a conformable one has not been satisfactorily decided, although, as we shall see presently, there is little room for doubt on the subject.

On the farms Platte Klip and Blood River an easterly projection of the Witteberg Beds is caused by an anticlinal fold with its axis pitching east-north-east. South of Eland's Vley there are slight swelling ridges of quartzite running south-east from the main mass of Witteberg Beds into the Dwyka Conglomerate country. It is uncertain whether these folds were produced before or after the deposition of the conglomerate.

With regard to the nature of the Witteberg Beds themselves there is nothing to add to the descriptions in former Reports.* The characteristic but now somewhat discredited fossil, *Spirophyton*,† was found in the northern part of the Zwart Ruggens, and also some rather good specimens of a Lepidodendroid plant, resembling the *Cyclostigma* of the Australian lower Carboniferous Beds. Both the *Spirophyton* and *Cyclostigma* came from a horizon at a considerable distance below the top of the group. These impressions of *Cyclostigma* are better specimens of a plant that has long been known to us from the Witteberg rocks of the Worcester and Ladismith Divisions; many specimens have been obtained from the neighbourhood of Grahamstown and the Kowie, and are preserved in the Albany Museum.

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* Ann. Rep. Geol. Com. for 1896 (p. 28), 1897 (pp. 19, 55, 64), 1898 (p. 61), 1899 (p. 35), 1900 (p. 77, etc.).

† Seward, Ann. S. A. Museum, Vol. VI., Pt. 1, pp. 103 6. Mr. Seward concludes that *Spirophyton* was inorganic in origin, an opinion that is not concurred in by the staff of the Commission, on account of the clear definition of the better specimens and the inadequate explanations offered on the supposition that they were of mechanical origin.

A remarkable dyke-like fissure, filled with a greenish grit, traverses the Witteberg Beds near Eland's Vley. The fissure crosses the Doorn River just below the confluence of the Tra-Tra, and on both sides of the Doorn River sections on the banks expose the fissure fairly well; it is also well seen on the right bank of the Doorn River, about three miles south of the Eland's Vley house. The fissure is about 8 feet wide, and maintains that width wherever it can be well seen. This gap in the continuity of the whitish quartzites naturally makes a somewhat conspicuous feature on the surface—in fact, it looks very like an old straight road, partly covered over with angular fragments of quartzites from the rock on either side. Where the fissure is cut through by a more or less vertical face of a cliff, as on the banks of the rivers, it is found to run vertically from top to bottom of the cliff, and to maintain its width and the character of the in-filling material throughout. On the cliff on the right bank of the Doorn River below Eland's Vley house, the vertical depth of the dyke exposed is about 50 feet, but much of it is buried under fragments of quartzite. In this place the greenish grit contains rounded fragments of quartz up to 1/10th inch in diameter. At the same locality, as on the right bank of the Tra-Tra, a slight dip away from the fissure is observed in the quartzites on either side and within seven or eight feet of it; in no case, however, was this dip as high as 10°, although sufficiently marked to attract attention and to require explanation. It was impossible for us at the time to follow the fissure as far as it is said to extend; the whole length seen by us, including the part hidden under an outcrop of Dwyka Conglomerate, was about seven miles, measuring the distance between the two outcrops furthest removed from each other. Mr. Hough, the owner of Eland's Vley, assured us that the fissure can be followed for six hours across the veld in a north-westerly direction, which means about 36 miles. The bearing of the fissure near Eland's Vley is almost exactly north-north-west.

The grit which occupies the fissure is composed of rounded and angular grains of quartz, microcline, garnet, and greenish muddy matter, such as that which forms the basis of many argillaceous sedimentary rocks. It resembles to some extent

The country to the east and north of the Roggeveld-Komsberg escarpment has a very gradual slope to the north, although the surface is sufficiently diversified by ridges and table-shaped hills. A long group of ridges can be traced from the western end of the Nieuweveld near Bontberg to Sutherland, thence west-north-west to the Great Fish River at Koornland's Kloof; from the Great Fish River these hills run north-north-west to Middle Post, and into the Zwarte Bergen and Klip Fontein's Berg in Calvinia. These ridges are due to the presence of the intrusive dolerite, the outcrops of which have been cut into very complicated forms by denudation acting now on nearly horizontal sheets and now on inclined masses of the rock.

To the south of Komsberg the high and broad ridge known as the Klein Roggeveld extends to within twenty miles of the main line of railway at Matjes Fontein. Several wide tongues of high ground stretch westwards from the Klein Roggeveld into the Ceres and Tanqua Karroo.

To the west of the Roggeveld and Klein Roggeveld there is a tract of lower ground varying from twenty to thirty miles in width, and extending from Klip Rug Kop on the north to Karroo Poort in the south, a distance of about 100 miles; from Karroo Poort the low country is continued eastwards between the Matjes Fontein hills and the Klein Roggeveld, and is connected with the Great Karroo through Laingsburg. This low country lies between 1,100 feet (Eland's Vley) and 2,000 feet above the sea, and is known under the names of the Tanqua Karroo in the north, and the Ceres or Bokkeveld Karroo in its southern portion and, as a whole, it can be called the Western Karroo.

To the west of the Karroo rise the Zwart Ruggens, a bare and dry dip-slope of Witteberg Beds, continued round the south of the Ceres Karroo by the Bontebergen. The Tanqua Karroo is drained by the Tanqua and its tributaries; the main stream enters the Doorn River at Eland's Vley. Dry throughout the greater part of the year, it is only after rains that water can be freely obtained in the Western Karroo. Although seemingly more favourably situated for the occurrence of rain and springs than the Great Karroo, the Western Karroo appears to be a drier country than the Gouph, and springs are certainly fewer there than in the western part of the Gouph.

The Doorn River, fed by the rains that fall on the eastern slopes of the Cederbergen and in the Cold Bokkeveld, contains a great body of fresh water during eight months of the year. It leaves the Zwart Ruggens by a great gorge with almost vertical sides, and flows for some twelve miles along the western boundary of the Karroo, but unfortunately at so considerable a depth below the general surface of the Karroo that no attempts have yet been made on anything but the smallest scale to take

cut the water and lead it over the adjoining ground. To a person who reaches the Doorn River after a long journey across the Karroo the sight of so much clear water is indeed welcome, but at the same time he is full of regret that use is not made of the immense volume of water that is now permitted to run straight to the Atlantic Ocean. The Doorn River receives tributaries from the southern part of the Western Karroo, which together form the Dwequa or Salt River (Groot River).

The sedimentary formations that come within our area include the uppermost part of the Witteberg Series, the whole of the Dwyka and Ecca, and the lower part of the Beaufort Series; in addition to these sedimentary rocks we have to deal with an important part of the dolerite intrusions of the interior of the Colony, and with an extremely interesting group of volcanic rocks occupying but a very small proportion of the whole district. Some gravel and alluvial deposits are of importance in the Tanqua Karroo.

Our district forms part of the edge and interior of the south-western corner of the interior basin of the Cape Colony. The southern boundary of the basin is due to folding, which has taken place subsequently to the deposition of the rocks occupying the interior, but the western boundary is not solely due to the same cause. In its southern portion the western limit is due to folding, but on tracing it northwards the Dwyka Series, the lowest number of the interior group, becomes less and less affected by folding, and at the same time is separated from the underlying beds by an unconformity that increases steadily in value towards the north, showing that the original western edge of the area of deposition of the Karroo formation was at a certain period not far from the present outcrop of the Dwyka.

The southern boundary-folds were produced by a force acting in a north and south direction, and the western ones by an east and west force. The two groups of folds meet in the neighbourhood of Karroo Poort, and a complicated structure is the result. The diagonal folds, directed approximately north-west and north-east, that occur over a considerable area, from the Cold Bokkeveld to the south-east limit of the Ceres Division, may be regarded as due to the conflict betwen the two sets of forces.* Outside our district, in the country between Ceres and Bredasdorp,† the resultant diagonal folds are much more marked than in the Karroo Poort region, and occur to the almost complete exclusion of others. The north-west folds are seen near Karroo Poort in the Drie Fontein Dwyka outlier, and in many minor flexures of a monoclinal nature that give the outcrops of

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* This type of structure is distinct from an arc, and has received the name of Schaarung in German or Rebroussement in French, but there is no English term to express the meaning.

† Ann. Rep. Geol. Com. for 1898, pp. 42–47.

The country to the east and north of the Roggeveld-Komsberg escarpment has a very gradual slope to the north, although the surface is sufficiently diversified by ridges and table-shaped hills. A long group of ridges can be traced from the western end of the Nieuweveld near Bontberg to Sutherland, thence west-north-west to the Great Fish River at Koornland's Kloof; from the Great Fish River these hills run north-north-west to Middle Post, and into the Zwarte Bergen and Klip Fontein's Berg in Calvinia. These ridges are due to the presence of the intrusive dolerite, the outcrops of which have been cut into very complicated forms by denudation acting now on nearly horizontal sheets and now on inclined masses of the rock.

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"pavement" are three feet in diameter, beautifully smoothed and striated parallel to the striations on the other similarly placed boulders. Where a fair-sized area of the rock without large boulders is exposed, the matrix of the conglomerate is ploughed up into furrows of various depths up to 1 inch, and of different widths, although each furrow maintains its width for a considerable distance. These furrows run parallel to the main striae on the boulders. There can be no doubt that this striated surface is not a fault-face; the character of the furrows in the matrix of the conglomerate is quite unlike the slickensides on a fault-face. The feature may easily be explained by the supposition that a mass of ice moved over the surface of the conglomerate already deposited, which was a stiff mud containing large and small boulders; the moving ice would tend to arrange the boulders it came into contact with, flush with the general surface of the mud; it would scratch all boulders so pressed into the mud in the same direction, and it would plough up furrows in the soft matrix. The striations and furrows indicate that the ice moved eastwards. It is impossible to determine at present the western limit of the "pavement," probably denudation has removed all the evidence on that point, so that we cannot know where the ice left the solid rock and passed over the boulder clay, or even whether the ice was directly connected with a large mass of land ice. However, it seems probable that the "pavement" was produced by land ice, for the movements of a stranded iceberg or pack ice are not likely to have been so regular as the movements of the ice that was responsible for the Eland's Vley "pavement" seem to have been. This is the first example of a "striated" pavement" found in the Dwyka Conglomerate, and it would probably have escaped notice had not the attention of the owner of the farm been attracted by the well-marked striae on some boulders on the outcrop; for thinking that the scratches were due to a rush of underground water, he ripped off the overlying rocks to find the source of the water and thereby exposed the "pavement." There is no marked difference between the rock above and below the "pavement."*

To the east of Eland's Vley there is a prominent boulder-bed in the Conglomerate; the boulders are unusually large and numerous in a band from 10 to 15 feet thick, and many of them are well striated. The Conglomerate is laminated below the boulder-bed, but contains smaller and fewer boulders. The boulder-bed was traced for a considerable distance, over 15 miles, along the outcrop from north to south; it is admirably exposed near the drift through the Tanqua, on the Calvinia main road, a few hundred yards west of the road on each side of the river. The matrix of the Conglomerate in this boulder-rock is the same as in the rock above and below, and it is probable that the boulders were dropped from floating ice in greater numbers than elsewhere on the bottom now represented by the boulder-bed. The rock above the boulder-bed differs from it merely in the less abundance of boulders.

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* A good account by G. K. Gilbert, with illustrations, of a boulder-pavement exposed on the shore of Lake Ontario, will be found in the Journal of Geology, 1898 (p. 771). References are there made to earlier literature on the subject.

Near the well on Witte Vlakte West (Calvinia) there are large exposures of an argillaceous sandstone, with both vertical and horizontal tongues of pebbly conglomerate penetrating them. They remind one of the " contorted drift " of the European Pleistocene glacial period, such, for instance, that can be seen on the cliffs of Norfolk and Suffolk. There can be no doubt that the contortions are original features and not due to earth movements, for they occur in a district where there are no signs of other than very slight disturbances in the well-bedded rocks, and there are no slickensided surfaces in the outcrop such as would certainly be produced in a crushed and crumpled rock.

Some parts of the Conglomerate are highly calcareous; the calcareous matter may be confined to spheroidal masses of conglomerate, or distributed throughout thin lenticular beds. The spheroidal lumps weather out from the surrounding rock in great numbers in certain areas. They are particularly abundant near Ratel Fontein, in the north of Ceres.*

Masses of white or light coloured quartzite of lenticular shape occur in the Dwyka Conglomerate on Beukes Fontein and Wardouw. They form several kopjes, four of which are on the same line of strike. The rock is a fine to coarse false-bedded quartzitic sandstone with pebbles of quartz, quartzite, felspar, grits, and slate. The sudden appearance of a rock so different from the usual type in the midst of the Dwyka Conglomerate is peculiar; the beds are not more than 25 feet thick. Many similar patches of quartzite were noticed between Karroo Poort and Tover Kop, and still further east. They are of the same nature as the quartzite kopjes of Matjes Fontein. It is probable that they were lenticular beds of quartz-sand deposited in hollows on the conglomerate, and subsequently covered up by conglomerate of the usual type. It is difficult to understand the reason of their extremely local character. In some places in other districts (Graham's Town, and near Drieling's Kloof south of Laingsburg) definite beds of quartzite have been found in the conglomerate, very like the lenticular quartzites of the Ceres Division, but having a very much greater length in proportion to their thickness.

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* The spherical nodules are also very numerous near Zout Kloof (N.W. of Laingsburg); Dr. Nobbs, of the Agricultural Department, recently brought to the Office of the Commission a typical specimen of one of these nodules from the Kalahari, 80 miles north of Upington, where there is an outlier of Dwyka Conglomerate.

The thickness of the Conglomerate is difficult to measure closely in this district, on account of the variable dip and the width of the strip of country occupied by it; it is probably not less than 1,000 feet thick near Beukes Fontein, but it seems to become thinner to the north .

The Conglomerate passes upwards into the Upper Shales by the gradual decrease in the number of pebbles and by the better lamination of the rock. The lowest part of the Upper Shale group is composed of bluish black and green thinly laminated shales; the darker coloured shales have a tendency to weather white, but they do not do so to the same extent as the black shales of the "White Band" higher up in the group. The bluish-black and green shales are about 250 feet thick, and are succeeded by thin sandstones, dark blue or greenish in colour when freshly broken, but weathering to pale green and light grey. There is much shale in this group, and 100 feet of thin sandstones, which pass upwards into the black shales that weather white, and make a conspicuous white band on many of the hillsides in the western and northern parts of the Karroo. These shales become less black in colour near their upper limit, where they contain several interbedded bands of chert, the uppermost of which is taken as the top bed of the Dwyka Series. The thickness of the "White Band" and the overlying shales and cherts is about 200 feet. It was in the thin sandstones at the base of the White Band that some remains of *Mesosaurus* were found east of Nieuwoudtville during a former journey, but no other specimens have since been obtained in the western Karroo. Some indistinct linear markings that are probably of organic origin are found in some of the black shales, but no recognisable plants have yet been met with in the Upper Dwyka Shales of this part of South Africa.

The upper part of this shale group contains beds highly impregnated with carbonates of lime, magnesium, and iron; some of them are now entirely crystalline, the individual crystals, as shown by the cleavage faces, stretch from the upper to the lower limit of the beds, which in such cases are not more than three inches thick. The carbonates at places show a fibrous structure, like the "beef" of quarrymen in the Purbeck and Portland districts in England. These calcareous beds appear to be re-crystallised calcareous deposits, and not veins formed parallel to the bedding planes of the shales. The iron carbonate has furnished the hydrated oxides of iron that stain much of the rock-surface in their vicinity. The beds, which in addition to the carbonates contain a fair amount of clayey matter, weather very curiously; the iron oxides derived from the carbonate are concentrated along the joint planes, and the argillaceous substance between the joints is easily removed by the wind and rain, so that the rock surface becomes a net-work of hard impure iron oxides with deep holes within the meshes. Some of the ferruginous rocks are cavernous, and the cavities are lined with quartz crystals, amongst which well-formed bipyramidal crystals are found. Iron pyrites is disseminated through the black shales and some other beds in the Upper Dwyka Shales; by the mutual decomposition of the pyrites, carbonaceous matter, carbonate of lime, and the aluminous silicates in the shales, when exposed to air and moisture, the hydrous sulphate of alumina and potassium and sulphate of lime (gypsum) are produced. The former, alum, is one of the chief constituents of the brak water so frequently obtained in wells sunk in the Dwyka Series, but it seems to be produced more abundantly in the Upper Shales than in the Conglomerate. The production of these salts takes place rapidly when the black shales are freshly exposed in water cuttings or wells; the exposed surface becomes covered with a thin incrustation of the sulphates within a few months; the incrustation is naturally thickest along lines of slight oozing in the section. The white salts are often stained yellow, red, or brown, by hydrated iron oxides.

The chert beds vary in number and thickness; sometimes there are as many as six, as in the neighbourhood of Tover Berg. The chert is usually very dark coloured when freshly broken, but it soon gets a grey or white crust. This chert was a favourite material with the aborigines for the making of rude knives and other tools and weapons, on account of its smooth fracture and the ease with which a sharp edge is obtained on a chip. At certain places on the outcrop of the chert there are great numbers of imperfectly-formed weapons; one of these localities is to the east of Beukes Fontein, which must have been a convenient spot for their manufacture. Although several specimens of the chert from the top of the Upper Dwyka Shales from various parts of the south and west of the Colony have been examined for minute organic remains, none has been seen in them. North-west of Tover Kop the uppermost bed of chert attains a maximum thickness of 30 inches, and below it are at least five other chert beds, the second (from the top) being 20 inches, and the others from 6 to 12 inches thick. Some of the chert beds are nodular; rounded lumps about ½ an inch in diameter, either isolated or connected with other similar lumps, weather out on the surface, and when the rock is broken the spherical concretions are seen to be rather darker in colour than the rest of the rock.

THE ECCA SERIES.

The Ecca Series covers a large part of the district, practically the whole of that part of the Ceres Division which lies east of the Calvinia road and north of a line drawn from Groot Zand to Patatas River, an area of over 1,500 square miles in extent; an area of some 600 square miles in the portion of the Tanqua valley that lies in the Sutherland Division; and a considerable though narrow stretch of country in the south of Calvinia between the Hantam and the Tanqua River. The Ecca Beds are rather disturbed in the southern portion of the area, but the dips become less towards the north, and in Calvinia the beds lie nearly horizontally.

The small area occupied by these beds north of the Tanqua compared to that south of the river is due to the protection afforded the sedimentary rocks by the sheets of dolerite in the north. The Roggeveld escarpment, which is capped by beds which probably belong to the Beaufort Series, is cut back very slowly on account of the sheets of dolerite, three or four in number, that have preserved the steep face of the escarpment during the process of denudation. Where the dolerite sheets cease, the escarpment becomes deeply embayed by the Tanqua and its affluents from the north-east; and the slope of the Klein Roggeveld, which lies wholly outside the dolerite country, is, as a whole, much less steep than that of the Roggeveld. The Beaufort Beds have mostly been removed from the country west of the Klein Roggeveld, but outliers and ridges projecting from the main mass of beds remain to prove their former westward extension.

The basement beds of the Ecca Series, as seen along the Baviaan's Krantz River between Matjes Fontein and Laingsburg, consist of very hard dark blue shales and sandstones, amongst which soft beds occur, but these are thin and infrequent. North of Matjes Fontein the lowest beds become more shaly in character, with occasional hard sandstones, which give rise to east and west ridges, well seen on the road from Matjes Fontein to Dwars-in-de-Weg. Westwards, on Vogelstruis Fontein, they become softer, and at Patatas River they consist chiefly of soft dark-blue shales with occasional calcareous nodules; hard beds only occur immediately above the top of the Dwyka Series.

Very interesting is the occurrence on the farms De Rante, Doorn Kloof, and Riet Kloof, of a bed of fine white quartzite about 150 to 200 feet above the Dwyka Beds. It is from 20 to 24 inches thick, and in places becomes a chert, resembling the chert beds of the uppermost part of the Dwyka Series, and liable to be mistaken for one of these; but the absence from immediately below it of the White Band with its calcareous and ochre-gypsum beds proves it to be quite distinct. It is underlain by hard bluish shales with thin sandstones.

North of the Dwyka anticline on Vogelstruis Fontein the folded Ecca Beds have high dips to the north reaching 75°, but in the hilly ground the folds die out rapidly and the mountain are capped with horizontal shales with massive sandstone beds.

One prominent flat-topped peak on the north-east boundary of Vogelstruis Fontein seems to be the Klein Tafel Berg of the old maps, and is mentioned both by Bain[*] and Wyley.[†] The former records the occurrence of the silicified stem of a large tree about 20 feet in length, and the latter some plant remains similar to those obtained by Bain from the Great Fish River, evidently specimens of *Schizoneura*. Wyley's plant remains are from the top of the peak, which is formed of the lowest beds of the Beaufort Series, but the same plant was found by the Survey lower down at Dwaars-in-de-Weg, at about the middle of the Ecca Beds, and at the time thought to be a stem of *Phyllotheca*.

From Patatas River westwards along the plain of the Groot River and then northwards along the plain of the Ongeluk's River, the character of the lowest beds of the Ecca remains unchanged. The beds immediately above the White Band are hard blue shales, which weather to a reddish colour, but they are succeeded by several hundred feet of fine soft blue-black shales with abundant calcareous nodules and occasional impersistent limestone bands. The nodules are often of a large size and exhibit beautiful "cone in cone" structure; they occasionally contain small cubes of iron pyrites commonly altered to limonite. The shales on weathering crumble very readily, and for considerable distances along the plain of the Ongeluk's River no dips are seen except where the beds are exposed in river beds or in artificial openings. The dips are small and variable in direction and north of Droogе Kloof the beds are thrown into many gentle undulations, the folds trending somewhat to the north of east. Hardly any fossil leaves occur in these beds, but fossil wood is by no means uncommon, *e.g.*, on Groot Gemsbok Fontein.

The character of these basement beds remains unchanged for many miles to the north, even beyond Calvinia. Their outcrop is often marked by a wide plain, as at the foot of the Koedoes Mountains and near Calvinia.

The middle and upper portions of the Ecca Series build up the mountainous country to the east, which is drained by the Smit's Winkel, Muishond, Ongeluk's, and Gemsbok's Rivers in the Ceres Division, and by the Tanqua and its tributaries in the Sutherland Division. The soft shales of the lowest division pass upwards into hard shales in the middle division of the Ecca; these contain occasional bands of dark, hard, fine-grained sandstone, and then again massive blue sandstone, weathering into rounded blocks and rather softer yellowish sandstones containing indistinct plant remains. These sandstones are often of considerable thickness and form two very well defined krantzes, well seen on Bantam's Fontein, Lower Roodewal, Bakoven's Kloof, and further to the north. They are usually whitish-grey or bluish sandstones, well banded and strongly ripple-marked, with occasional softer bands of blue spotted sandstones, flaggy sandstones, or hard mudstone. They appear to get thicker and more like the "defining" sandstones of the Beaufort Beds as they are followed northwards, and attain their greatest development a little north of the Gemsbok River, building up the mass of the Schoorsteen Berg, which rises about 2,500 feet above the plain of the Ongeluk's River.

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[*] Trans. Geol. Soc., London, Vol. VII., p. 188.

[†] "Notes on a journey in two directions across the Colony," Cape Town, 1858, p. 9.

The basement beds of the Schoorsteen Berg are soft black shales, of which about 1,000 feet are exposed between the main road and the lowest sandstones, but allowing for beds occurring to the west between the road and the White Band, there must be fully 1,400 feet of shales above the Dwyka Series. Above these basement shales come about 1,200 feet of hard shales with banks of massive "defining" sandstone, pale blue when freshly broken and weathering spheroidally with a pale grey or yellow colour, and occasionally of great thickness; the second is no less than 200 feet and the third 100 feet thick. The sandstones are usually fine-grained, but are occasionally coarser and felspathic; they often contain quartzitic concretions which weather brown externally. Indistinct plant remains were found in these beds.

The remaining 400 feet of strata on Schoorsteen Berg belong to the upper division of the Ecca Series, and consist of hard flaggy shales with hard, ripple-marked, spotted sandstones. The actual summit of the mountain is formed of a hard capping of this sandstone, about 150 feet high and 50 feet in diameter, with a perfectly flat top. The mountain sides are steep, for the sandstone forms abrupt krantzes, while the hard shales continually break away, leaving a steep slope, and the base of the mountain is covered with piles of material brought down by landslips.

While only a small amount of the uppermost beds are present on Schoorsteen Berg, the full thickness is seen in the Koedoes Mountains to the east owing to the gradual easterly dip of the beds. Along this range, which forms the boundary between Ceres and Sutherland, there are fine exposures, due to the presence of the lofty krantzes on the farms Hooge Vlakte, Zout River, and Waterlemoen Fontein. The rocks consist of massive sandstones, which have a reddish colour when weathered; they are thinly capped by beds, which have been mapped as belonging to the Beaufort Series.

The thick sandstones of the middle Ecca Beds can be traced north-east from Schoorsteen Berg across the farms Vaal Fontein and Waterlemoen Fontein, and thence south-eastwards up the valley of the Tanqua; but within a short distance the character of the sediments has changed to a great degree. The massive sandstone bands have thinned rapidly, and on Waterlemoen Fontein, at a distance of 12 miles, they are represented by two thin banks, with about 150 to 200 feet of shale between them. Since this parting of shale is 230 feet thick at Schoorsteen Berg, it is evident that the sandstones thin out in a north-easterly direction, and are replaced by shaly material. As these beds are traced eastwards as far as Blaauw Heuvel, only one of the sandstones—the upper one—remains; its peculiar pale blue colour and large calcareous quartzitic nodules make it easily recognisable. At the junction of the Hout Hoek River with the Tanqua this sandstone forms prominent cliffs along the river banks. Where weathered, blocks of it becomes spheroidal and of a whitish-yellow colour, but when fresh it breaks away along vertical joints, and forms a cliff much resembling that formed by a columnar dolerite sheet; this resemblance being heightened by the occurrence just above it of a thin band of almost black, vertically jointed quartzite. The blue sandstone varies greatly in thickness, differences of from six to thirty feet may be observed in a short distance. About four miles further up the Tanqua, this same sandstone is again exposed in the river bed and covers a considerable area. It is traversed by beautifully clear sharp vertical joints running continuously from end to end of a given exposure (as much as 200 yards even) and in a north-north-west—south-south-east direction, and the rock is cut up into rectangular blocks by short transverse joints. The bed of sandstone is only two feet thick at this point, so that in a distance of eighteen miles two beds of sandstone of total thickness of 300 feet have been reduced to this insignificant stratum.

As at Schoorsteen Berg, the beds above this sandstone are hard blue shales with their dark blue sandstone layers and their impersistent bands of black compact limestone, followed by dark shales with very large flattened limestone nodules from six to ten inches thick and many feet across. Silicified wood and indistinct plant remains occur in these beds.

The lower and middle Ecca Beds, when followed across to the right bank of the Tanqua, up the Rhenoster River, and along the face of the Roggeveld escarpment become very much alike in character, and no division can be drawn between them.

The uppermost beds of the Ecca Series, which are so massive on the farms Hooge Vlakte and Zout River are also seen to vary considerably in character when followed northwards and eastwards. The massive sandstone beds become more shaly on Waterlemoen Fontein, and on the north bank of the Tanqua, on the farms Drie Fontein (Ceres), Paul's Hoek, etc., they consist of thin beds of sandstone alternating with hard blue sandy shales; when followed along the Roggeveld escarpment, they pass into hard blue fine-bedded sandstones and shales, and this character remains unaltered as far as the beds were examined.

In the Tanqua basin the upper series is represented by thin but massive sandstone bands, which are sometimes irregularly bedded and which weather spheroidally; spotted sandstones are common, but blue shales are rare, the softer beds being greenish mudstones and sandy shales. Local unconformities are occasionally seen, *e.g.*, a little north of Zeekoegat. Calcareous nodules are common in the sandstones and also ferruginous patches, due to altered pyrites, but calcareous nodules or limestone bands in the softer beds are infrequent.

As these beds are followed from the Tanqua basin southeastwards into the valley of the Ongeluk's River (Ceres), they are found to change their character and become more arenaceous, thus returning to the type seen at Hooge Vlakte and the valley of the Gemsbok River. At the head of the Ongeluk's River, on the farm Olivier's Berg, there is a bed of sandstone about 6 to 8 feet thick, and this when followed westwards thickens out on Gat's River to at least 100 feet in a distance of about six miles.

Plant remains are abundant in these upper beds; *Gangamopteris* was recorded from a point a little north of Tuin Plaats or Vinke Kuil, in the Tanqua basin; *Glossopteris* from several places; *Schizoneura* and *Phyllotheca* from Olivier's Berg, as well as many indeterminable fragments of stems and leaves.

The character of the Ecca Beds in the Roggeveld escarpment may be illustrated by a section taken on the eastern side of Zand Kop (Kreit's Berg), south-east of Calvinia; the lowest beds are not seen there, and the section commences in the shales some 500 or 600 feet above the top of the Dwyka Series:—

Dolerite at top of Zand Kop	70 feet.
Thin bluish sandstone weathering pale grey (Beaufort Beds	60 „
Dolerite	50 „
Hard blue flinty sandstones	60 „
Dolerite (coarse, yellow-weathering rock)	340 „
Thin bluish sandstones and shales weathering yellow	570 „
Black shales with thin sandstones	220 „
Dolerite	50 „
Black shales with limestone nodules	230 „
Sandstone	2 „
Black shales with limestone nodules	150 „
House on the farm Keiskie	— „
	1802 feet.

There were no fossils found in this section ,and it is uncertain whether the uppermost sandstones belong to the Beaufort Beds, to which they may however be provisionally referred. The dolerite is 510 feet thick altogether, leaving 1,292 of sedimentary rock, of which the top 70 feet probably belong to the Beaufort Series.

A section measured on the western end of the Hantam Berg near Calvinia gave the following results:—

Dolerite (on which a large beacon is placed)	50 feet.
Yellow sandstone (Beaufort Beds?)...	70 „
Thin flaggy grey sandstone	245 „
Dolerite	20 „
Shales	15 „
Dolerite	10 „
Hard blue and green shales	440 „
Dolerite	20 „
Black shales	310 „
Dolerite	10 „
Green and black shales with limestone nodules	510 „
Dolerite	200 „
Greenish black shales with limestone nodules	210 „
	2,110 feet.

The Hantam section commences in the shales above the Dwyka Series, but at a lower horizon than the Zand Kop section, and deducting the dolerite (300 feet) and the 70 feet of Beaufort sandstone, we have 1,740 feet of Ecca Beds, to which perhaps 100 feet of black shales must be added to bring the section down to the bottom of the series.

In the mountain called Roep-my-niet, a few miles south of Calvinia, there are probably 240 feet of Beaufort Beds at the top, resembling those on Zand Kop and Hantam Berg, and about 1,700 feet of Ecca Beds, but the top of the Dwyka Series lies some distance below the base of the mountain, which rises from about the same level as the Hantam Berg. *Schizoneura* was found in the Beaufort sandstones at the top of Roep-my-niet.

The thin sandstones and shales of the upper part of the Ecca Beds often form a nearly perpendicular krantz near the top of the Roggeveld escarpment. They are traversed by vertical joints, which run through a very considerable thickness of rock. Occasionally there are three sets of such joints, which give the krantz a roughly columnar form.

The outliers of the Roggeveld called Groot and Klein Tafel Berg consists of a rough surfaced sheet of dolerite 300 feet thick, near the base, followed by a vertical krantz of thin blue and grey sandstones and shales, 50 feet thick, which are capped by yellow-weathering sandstones, probably the base of the Beaufort Series.

The whole thickness of the Ecca Beds in the Roggeveld between the Tanqua Valley and Calvinia is probably between 1,800 and 2,000 feet, considerably less than in the Koedoes Berg, but there is always some uncertainty as to the exact position of the dividing line between the Ecca and the Beaufort Series in the absence of a well-defined palæontological or lithological horizon.

THE BEAUFORT SERIES.

The rocks assigned to the Beaufort Series in this area show some points of difference from the beds belonging to the same group in Beaufort West. Reptilian remains are much less abundant in the Roggeveld and Komsberg than in the Nieuweveld and Gouph; and the beds as a whole are perhaps more arenaceous than further east.

In the Report on the western part of the Gouph and Moordenaar's Karroo,* reasons were given for drawing the boundary between the Ecca and Beaufort Beds along the high ground north of Dwars-in-de-Weg. From those hills which lie at the south end of the Klein Roggeveld westwards, the sandstones at the base of the Beaufort Beds are continued round the brow of the Klein Roggeveld escarpment, which is here deeply cut into by the head streams of the Barend's Kraal River, and by those of the Dwequa (Salt or Groot River). An outlier caps a prominent hill on Vogelstruis Fontein. Two tongues from the Klein Roggeveld project into the Ceres Division, on either side of the Ongeluk's River. To the north of these projections the Tanqua and its southern affluents have cut back far into the Klein Roggeveld, almost separating it from the Roggeveld, which rises a few hundred feet higher to the north. The Koedoes Mountains, on the south side of the Tanqua, are capped by an outlier of the Beaufort Beds, and several smaller outliers intervene between the Koedoes Mountains and the Klein Roggeveld.

The boundary of the Beaufort Series can be followed from Verlaten Kloof all along the Roggeveld escarpment, in a north-westerly direction for about 65 miles, until the Bosch Kloof River is reached. The boundary then bends round towards the north and afterwards towards the north-east, but the ground was not examined beyond the Tafelbergs.

The division between the Ecca and Beaufort Beds in the Tanqua valley is never sharp, and the boundaries are thus only approximate, and in addition we find the beds traversed by monoclinal folds, which increase the difficulty of separation. Farther to the north-west, however, from the north-eastern corner of the Ceres Division, there is always a sharp demarcation, the base of the Beaufort Beds being a reddish yellow massive sandstone, while below it comes a great thickness of dark blue flaggy shales, with a few dark sandstone beds. As far as the beds were mapped, this distinction held good.

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* Ann. Rep. Geol. Com. for 1902 (p. 112).

The lithological characters of the Beaufort Series in the Klein Roggeveld have been previously described.* Between the sandstones are beds of hard green mudstones, with green and purple sandy shales. Fragments of *Phyllotheca* or *Calamites* are common, and at Fortuin a portion of a *Glossopteris* frond was noticed.

As many of the valleys run north and south, the boundary of the Beaufort Beds is very irregular, especially on the Ceres border. At Olivier's Berg, on the main road from Ceres into the Tanqua Valley, there are many small tongues and inliers of Ecca Beds in the valleys, owing to the monoclinal folding. The thickness of Beaufort Beds capping the west extremity of the Klein Roggeveld cannot be great, the maximum, 800 feet, occurring probably at Olivier's Berg. The sandstones are often massive, yellow or bluish in colour, and very commonly "spotted"; purple and green mottled mudstones are abundant.

Clay-pellet conglomerate and calcareous nodules occur near the summit, but no fragments of bone were obtained from them. Plant remains are common; between Matjes Fontein and Olivier's Berg there were leaves and stems of *Schizoneura africana*.

In Verlaten Kloof fine exposures of Beaufort Beds are met with; at Klipbank's River the base of the Beaufort Series was drawn below a massive bed of mottled grey sandstone with peculiar dark grey quartzitic concretions. These latter are very irregularly scattered through the rock, and are almost perfect spheres, from half an inch in diameter up to about a foot or so, and sometimes several of them are found intersecting one another. They contain a large amount of carbonate of lime, with a little iron, and weather to a purplish brown colour. Further up the kloof massive sandstones are more numerous, and they are traversed by a series of vertical joints dividing the rock up into large rectangular blocks. At the top of Verlaten Kloof there are several bands of calcareous clay-pellet conglomerate, in which a few fragments of bone were found. Bands of limestone weathering brown occur below the conglomerate, but no reptilian remains were observed.

From a clay-pellet conglomerate a little further north, at Jackals' Valley, near Sutherland, a small pebble of granitic rock was obtained. At Langekuil, 20 miles, east by south from

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* Ann. Rep. Geol. Com. for 1902, p. 113.

Sutherland, there is a thin seam of coal below a sandstone krantz. A number of excavations have been made, and the continuity of the seam has been proved towards the west of the tableland; on the south and east, however, slate only is exposed. A horizontal drive has been put in at one point for about 60 feet, the roof of the tunnel being formed of massive sandstone, below which come soft light coloured clayey mudstones, resembling impure fireclay; the coal occurs at the bottom of this clay. The coal seam is from 8 to 9 inches in thickness, and is very uniform all along the drive. It is rather friable, and has a very high lustre, and from the following analysis made by Mr. J. G. Rose, of the Government Laboratory, it is seen to be of a very good quality:—

Fixed carbon	50.04	per cent.
Volatile matter	28.79	„
Ash	6.86	„
Moisture	14.31	„
	100.00	

A notable feature is the large amount of moisture in the coal, the average for the Stormberg coals being from 1.3 to 1.8 per cent.; the second feature is the small amount of ash which it yields, proving in this respect immensely superior to the coals of the Eastern Province. Unfortunately the coal when tried in a grate crumbled and refused to ignite, and in consequence the workings were abandoned, the coal proving valueless. The large percentage of moisture accounts for the friability of the coal.

About 200 yards north of the adit there is a shaft about 20 feet deep, in which this seam of coal occurs, while below it were two additional seams, which, however, we were unable to examine. Plant remains occur in the mudstones associated with the coals. About a quarter of a mile south of the adit these same mudstones yielded some fragments of large reptilian bones. A few miles to the north-west, at Uitvlugt, near the Fraserburg boundary, fragments of a reptilian skull were obtained close beside the farmhouse. Dr. Broom has pronounced these to belong to the genus *Titanosuchus*.

About four miles east of Sutherland occur massive "defining" sandstones, usually spotted with pink or green, often somewhat blotchy. They are often remarkably false-bedded, the angle of the laminæ being occasionally as high as 35°. They contain very large calcareous nodules which weather to a purplish brown colour; one of these was eight feet by three by two. Similar spotted sandstones occur to the west of Sutherland, on the farm Kruis River, and when altered by dolerite large green concretions are found, either round or tubular in form, and porbably largely made of epidote.

In the valley of the Great Fish River Bain[*] discovered a number of curious plants, which were named *Asterophyllites (?)* by Sharpe,[†] and later on *Schizoneura africana* by Feistmantel.[‡] Similar plants were obtained on the farm Wolve Dans and also on the adjoining property Mulder's Fontein, both close to the Calvinia boundary. It is probable that the former was the place whence Bain obtained his specimens. The plants occur in a very hard fine-grained greenish sandstone on the right bank of the Great Fish River, immediately opposite the farmhouse.

In Calvinia, about eight miles south of Middlepost, *Glossopteris* was found in a very coarse felspathic sandstone, while a little to the east of Bloemfontein *Glossopteris* was abundant, together with *Phyllotheca* or *Schizoneura.*

By far the most interesting find was the discovery at Knechts Banken, six miles north of Bloemfontein, of lamellibranch shells and fish scales, together with *Glossopteris.* The rocks consist of thin hard grey sandstone and sandy shales, and dark blue shales with black limestone bands about four or five inches in thickness. The shells are met with in all the beds, but only sparingly in the limestone; they are very badly preserved and difficult of determination. The genus is *Palaeomutela* and the species perhaps are *P. keyserlingi* and *P. rhomboidalis.*[§]

The discovery is interesting, because remains of mollusca have not yet been recorded from the Karroo beds west of Graaff-Reinet,[†] though they are evidently widely distributed; *Palaeomutela* has been found by Molyneux in the Sengwe coalfield in Southern Rhodesia.[||]

The fish scales resembled those of *Palaeoniscus,* described Bain's paper by Egerton.[¶]

Just a little below this fossiliferous horizon comes the basal sandstone of the Beaufort Series, well exposed on either side of the Bosch Kloof River, on Knegts Banken, and Karree Hout Rivier. This sandstone weathers yellow and caps the Klein and Groot Tafelbergs and the Klip Fontein Berg farther to the east. Northwards and westwards there are only beds of the Ecca and lower Series.

The outliers which occur on Kreits Berg, the Hantam, and Roep-my-niet Mountain have already been mentioned in the description of the Ecca Beds.

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[*] Bain. Trans. Geol. Soc. of London, Series II., Vol. VII. (p. 188), 1852.

[†] Ibid. (p. 225).

[‡] Feistmantel Übersichtliche Darstellung der Geologisch-Palæontologischen Verhältnisse Süd-Afrikas, Part I. (p.p. 41-2), Prag., 1889.

[§] Amalitsky. Comparison of the Permian Fresh-water Lamellibranchiata from Russia with those of the Karroo Formation. Quar. Journ. Geol. Soc., Vol. LI. (pp. 337-42), 1895.

[||] See note by W. Hinde in Quar. Journ. Geol. Soc., Vol. LIX. (p. 287), 1903.

[¶] Bain, loc. cit. (p. 226).

THE DOLERITES.

Sheets and dykes of dolerite play a very important part in the geology of the northern part of the area dealt with in this Report. In the southern part of the district only one intrusion has been met with, a dyke 350 feet wide at the widest part and 13 miles long from north to south; it traverses the Dwyka Conglomerate on the farms Beukes Fontein, Drie Dam, The Saltpans and Groot Fontein, and is inclined at a high angle towards the east. This dyke is an olivine-dolerite with ophitic structure, and contains the brown mica that is often found in the Karroo dolerites. There can be no doubt that it is one of the intrusions of the group to which the sheets and dykes of the Roggeveld belong, although it is about 14 miles distant from the nearest intrusion to the east. At the junction of the farms Groot Gemsbok Fontein, Nieuw Fontein, and Schoorsteen Berg there is a north-west dyke about three miles long which gives off three small sheets. A large sheet forms an outcrop about five miles long below Schoorsteen Berg. There are several small dykes on Quagga Fontein and Jackal's Fontein near the north end of the Ceres Division, and a dyke sixteen miles long runs north-westward from Waterlemoen Fontein in Ceres to Luiper's Kop in Calvinia. A similar but shorter one runs through Stonehenge and Bonte Koes-Hoek, at the south end of the Calvinia Division. The latter dyke is found to be of a more acid type than the typical olivine-dolerite of the Karroo; it contains no olivine and less augite, rather more mica, and a considerable amount of quartz intergrown with the outermost layer of the zoned felspars (plagioclase). Two dykes occur in the Tanqua valley on the farms Tuin Plaats (Vinke Kuil), Zeekoe-Gat and Tanqua Rivier. The Tuin Plaats dyke (Slide No. 992) has a porphyritic structure; the crystals of plagioclase and augite lie in a devitrified glass; some of the augite has a slight tendency to be ophitic and surround the felspar. There is no olivine in the slide examined, and the rock differs from the normal type of dolerite in the thick sheets and dykes in having a porphyritic instead of an ophitic structure.

The dykes we have mentioned form a sort of zone round the south-west end of the main mass of dolerites of the Roggeveld, and are either not connected with sheets or only with some (Schoorsteen Berg) that are insignificant when compared with those of the Roggeveld. It is possible that some of these dykes supplied sheets that have long since been denuded away. Small sheets, probably outliers of those to the north-east, occur on the south side of the Tanqua on the farms Ymasqua and Olivier's Kraal. They may have been connected with the first or second sheet in the Calvinia Division.

On the north of the Tanqua there are some small outliers and disconnected portions of sheets in the Upper Dwyka Shales and the bottom beds of the Ecca, before we come to a great sheet* that stretches in an unbroken outcrop from Potkly's Berg East, to the Oorlog's Kloof River, a distance of 54 miles in a straight line. It is probably connected beneath the surface with a similar sheet that appears a little lower down the Oorlog's Kloof valley on the right bank, and which is continued, with a few unimportant breaks, as far north as Loerie's Fontein. At the Oorlog's Kloof River this sheet is in the lower part of the Upper Dwyka Shales, but at Potkly's Berg East it is in the Lower Ecca, having passed upwards through some 600 feet of sedimentary beds in the course of 54 miles towards the south-east. This tendency of the sheets to invade a higher stratigraphical horizon towards the south-east is exemplified by all the sills that have been traced through a distance of many miles in this part of the Colony, and it results in the fact that in the Beaufort West Division the sills are confined to the middle and upper parts of the Beaufort Series, while in Calvinia they are equally abundant in the Dwyka and Ecca; in Sutherland, intermediate in position between Beaufort West and Calvinia, the sills are mostly in the Beaufort Beds, but a few are found in the upper part of the Ecca. (See Map and Fig. 1.)

The second sheet commences in the north-west near Drie Fontein as a thin sheet very near the thick offshoot (third sheet) of the lowest sheet, in the Upper Shales of the Dwyka Series; it is probably directly connected underground with the lowest sheet. The Calvinia-Ceres main road lies for some 14 miles between the outcrops of the two lower sheets, until it crosses the lowest along the Bosch Kloof River. The white band of the Upper Dwyka Shales separates the two sheets as far south as Leeuw Pads Vlakte, where the second sill breaks upwards into the Lower Ecca Beds, and it rises in position as far as Waai Kop in the extreme north-east corner of Ceres, where it lies fairly high in the Ecca Series. This sheet appears to die out altogether at Waai Kop, after a course of 50 miles in a straight line, although, of course, the length of the outcrop measured along the curves is much greater than this.

In the Eland's and Gemsbok Berg† this sheet attains a thickness of over 300 feet, and has an outcrop over three miles wide. It gives rise to rather rough surfaces, but less rough than some met with behind the Roggeveld escarpment. The two outliers south of the Tanqua, on Ymasqua and Olivier's Kraal, may belong to this sheet. Many outliers lie to the west of the main outcrop, capping the "White Band" on Eland's Berg and other parts of the escarpment, mainly formed by the lowest sheet.

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* See also Ann. Rep. Geol. Com. for 1900 (p. 51).

† A mountain lying about 70 miles south-east of the Eland's Berg already mentioned.

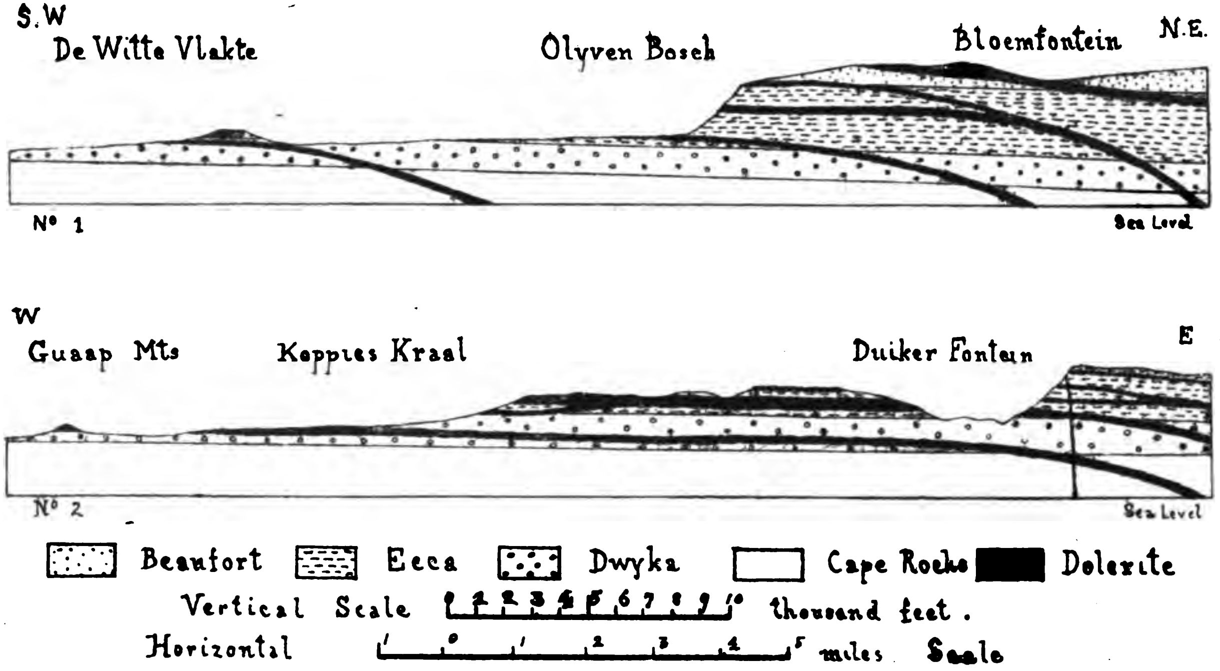

FIG. 1.—Sections through the Roggeveld Escarpment. No. 1 is taken along a line about 18 miles south of No. 2.

The third sill originates as an offshoot of the first near Platte Kloof and has only an independent existence for eight miles (in a straight line), as it joins up with the fourth sheet on Roode Fontein.

The fourth sill is the lowest dolerite mentioned in the Zand-Kop (Kreits Berg) section on p. 30, and has been traced as a continuous outcrop from Kreits Berg southwards for more than 50 miles along the face of the Roggeveld escarpment as far as Geelhoek in Sutherland. It gives off another smaller sheet shortly after being joined by the third sheet at Roode Fontein, where it is 200 feet thick and contains veins of calcite and galena. At Zand-Kop it is only 50 feet thick. East of Kreits Berg it makes a very complicated outcrop, owing to the partial removal of the overlying sediments, and it was probably once connected with thick sheet under the krantzes of the Tafel Bergs; matters are further complicated by this portion of the sheet rising towards Roode Fontein on the edge of the Roggeveld, and although it crowns the escarpment, it sends a branch down towards the north-west to the farm Kneu to join up with that portion of the sill already described. North and west of Kreits Berg the fourth sill is also well developed and covers wide but irregularly shaped areas between the Hantam Berg and Zand-Kop. It probably extends far to the north of Calvinia village. South of Roode Fontein the fourth sheet crowns the Roggeveld escarpment for some 20 miles, disappearing on Klein Fontein in Calvinia. Between Roode Fontein and Klein Fontein this sill gives off several masses to the east, and probably forms large areas east of the district that we examined. This sheet is generally rather less basic than many of the Karroo dolerites. Olivine is present in but small quantity, and in many sections of the rock is not seen at all; augite is less abundant than usual, and is in smaller crystals and plates, with the ophitic structure not so well developed as in the more basic rocks; plagioclase is in greater quantity than in the typical olivine-dolerites, and the larger crystals are often more or less surrounded by a micropegmatitic inter-growth of quartz and felspar. On Bloem Fontein and Kuil Water some very acid rocks form part of this sheet. The Bloem Fontein rock is made up of large radially arranged intergrowths of quartz and felspar, with some altered brown mica as the only dark-coloured constituent; it is a granophyre; the Kuil Water rock is also a granophyre with spherulitic intergrowths of quartz and felspar imbedded in a micropegmatitic ground mass, in which there is also a little altered mica. The Tafel Berg portion of this sheet disappears on the south near Knegts Banken, but it is probably continued far to the east of the Tafel Bergs. The sheet underlying the Tafel Bergs is a coarse-grained rock, and is rather easily decomosed; it breaks down into a pinkish grey muddy sand, out of which project huge boulders of less decomposed rocks.

East of Middlepost there are numerous dolerite sheets in the hilly country forming the boundary between Calvinia and Sutherland. One of these sills, consisting of very coarse dolerite, has been followed far up the valley of the Great Fish River, which it leaves at Ezel's Fontein, thence it crosses the divide between the Great Fish River and Rhenoster River, and passes five miles to the north of Sutherland. It is probably a continuation of the Kuilen Berg and Bontberg sheet, and these in their turn are almost certainly connected with the crowning sheet of the western Nieuweveld at the junction of the Sutherland, Fraserburg, and Beaufort West Divisions. The Bontberg gets its name from the brilliant red colour of the talus slopes below the dolerite cliffs; towards sunset the colours of this mountain, seen from the west, are very beautiful against the blue sky, with a background of the western cliffs of the Nieuweveld, which assume hardly less brilliant tints.

In the Great Fish River valley this sheet occupies a great extent of the surface on Riet Fontein, Vier Fontein, Koornlands Kloof and Ezel's Fontein; it approaches the edge of the Roggeveld escarpment at Quagga Fontein, and an outlier forms a very fine columnar cliff at least 300 feet high at Uitkyk (Boven Plaats) on the edge above the amphitheatre-like bay in the escarpment occupied by the farms Windhoek and Oude Berg. A second, but much less imposing outlier, which is capped by sedimentary rocks, occurs on the western boundary of Houdenbek, and this is the last dolerite sheet met with on the edge of the Roggeveld. From this point to the eastern beacon of Klippe Kraal, a distance of some 55 miles along the edge, the escarpment face is formed entirely of sedimentary rocks, and loses some of its abruptness, for the sandstones are less prone to give rise to perpendicular cliffs than the dolerite sheets. Along the Great Fish River the sheet varies very considerably in thickness, and is also much less regular in position than the sheets usually are, so that it may rise to cap the hill sides within a short distance of the valley bottom occupied by it. The rock is usually very coarse-grained, and weathers into huge piles of large slabs and blocks, which give to a range of kopjes the appearance of ruined masonry; this rough dolerite country is at places very difficult to traverse.

In the valley of a small tributary entering the Great Fish River from the west on the farm Houdenbek there is a very fine section showing the sudden thinning of the sheet. On either side of the valley there is a rough ridge of dolerite 150 feet thick, but where the sheet is cut through by the stream it is only 15 feet thick, and it maintains this thickness as far as the edge of the Roggeveld, about two miles to the west. The outcrop of the sheet in the stream bed is marked by a waterfall. The decrease in thickness takes place within a quarter of a mile.

In the Kuilen Berg portion of the sheet are veins of granophyre (a micropegmatitic intergrowth of quartz and orthoclase) traversing the olivine-dolerite that forms the greater part of it. (Slide No. 1032.) The vein is like a miniature dyke, a few inches in width, and the boundary with the dolerite is perfectly sharp; this contrasts with the gradation of the dolerite into the granophyre matter, as is seen in other cases. There can be no doubt that the acid rock represents a portion of the same magma that in most parts solidified as the olivine-dolerite, and probably it was the residue derived within the limits of the same sheet. A section cut from the uppermost portion of the Kuilen Berg sheet (Slide No. 1031) shows tne rock to be fine-grained and porphyritic; the porphyritic elements are augite and plagioclase, and the ground-mass is composed of small felspar laths and minute grains of augite and iron ores. This fine-grained rock is directly connected by intermediate stages with the usual coarse rock forming the bulk of the sheet, and evidently owes its character to the circumstance that it was more quickly cooled than the interior part of the sheet. It is usually found that thick sheets are coarser in grain than thin, and that the same relation holds between the coarseness and width of dykes.

A rather interesting sheet of rock is one which occurs on a peak known as Riet Kop a few miles north-east of Middelpost and on the Sutherland boundary. The sheet is from 250 to 300 feet thick and dips to the north-east at a high angle. It is mostly composed of a rather coarse grey rock which has decomposed to a soft friable mass, leaving in places rounded masses of unaltered material. The rock varies in character from a pale, almost granitic drusy rock near the base, sometimes very fine grained, to a dark compact columnar one at its upper surface, and it is apparent that the variation is due solely to differentiation of the molten magma. A section from the south-west side (Slide No. 1052) is very drusy, and has intergrowths of quartz and felspar (probably orthoclase) with yellow pseudomorphs after mica and brown hornblende. A section (Slide No. 1051) from the north side is drusy and shows large slightly clouded plagioclase phenocrysts, often zoned, surrounded by micropegmatitic intergrowth of quartz and clouded orthoclase, with a quantity of brown mica and yellow pseudomorphs after mica and perhaps hornblende, and a little ilmenite. Another section (Slide No. 1049) shows an approach to micropegmatitic structure by reason of the grouping together of the grains of quartz which extinguish simultaneously between crossed nicols. Long yellow-brown pseudomorphs after mica or hornblende are abundant. In the coarse-grained specimens the brown pseudomorphs may attain a length of an inch, and are often arranged in a radial manner. The abundance of quartz and orthoclase in micropegmatitic intergrowths shows that the rock ought to be termed granophyre. The basic type, as seen in a specimen (Slide No. 1053) from the south side, contains no quartz, but clear laths of plagioclase build up the bulk of the rock, and pale augite is present in grains and prisms, as well as a little brown mica, and the ground-mass is devitrified glass, with much dusty matter. This rock then also differs from the typical Karroo dolerites.

The last sheet that we have occasion to describe in this Report is the westerly continuation of the Rooi Hoogte inclined sheet or dyke.* It leaves the Beaufort West Division at Banks Gaten, and runs up the left bank of the chief head-stream of the Dwyka River; on the right of that stream it crops out high up on the mountain side on Alleman's Hoek, Wilgebosch Kloof, and Vinke Kuil, owing to the northerly dip of the sheet. The Alleman's Hoek and Wilgebosch portion has been cut off from the rest by a tributary of the Dwyka, and so forms an outlier. The Dwyka and its tributaries in this neighbourhood run in very steep-sided gorges, in which there are waterfalls caused by the outcrops of the dolerite. The dolerite forms rough columnar cliffs, gradually reaching higher levels towards the west and south. From Vinke Kuil this sheet trends westwards, splitting into two where crossed by the Phesante River; the northern branch attains a higher level than the southern, and is continued through Blaauw Blommetjes Keep to within a mile of the Sutherland main road.

In the sheets and dykes prehnite occasionally occurs in joints and cracks in the rocks—for example, on the farm Twee Fontein, a few miles south of Sutherland Village, and on Roode Fontein, on the edge of the Roggeveld. A small amount of galena was also obtained at the latter spot, where a prospecting shaft had been sunk on a vein in the dolerite.

The dolerite sheets and dykes have greatly metamorphosed the sedimentary beds into which they have been intruded. In some of the sandstones bright green nodules and "pipes" of epidote have been produced, often an inch or two across. More usually the rock becomes crowded with small indefinite spherules; a specimen of such a rock from Roode Fontein (on the Roggeveld) is seen in section (Slide No. 1058) to consist chiefly of quartz and a pale, almost colourless, chloritic mineral; granules of epidote are abundant, and there is also a little sphene. In another section (Slide No. 1059) a large amount of felspar is present in addition to the above-mentioned constituents. Sandstone fragments caught up by the dolerite are often rendered vesicular, and in a specimen from Onwetende Fontein, east of Calvinia, the vesicles are as much as half an inch in diameter. Calcareous rocks are often completely altered. Such a rock taken from above the dolerite sheet on Kuilenberg, east of Sutherland, has been completely re-crystallized, so that none of the original minerals remain. In section (Slide No. 1033) the rock is seen to be composed of large clear crystals of pale epidote enclosing small crystals of quartz and abundant garnets (grossular) from incipient growths up to crystals which are visible to the unaided eye.

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* See Ann. Rep. Geol. Comm. for 1896 (pp. 21 and 22) and ibid. for 1902 (p. 122).

A bleached or "white" sheet of dolerite occurs in the black carbonaceous shales of the Upper Dwyka beds at Blaauw Krantz (Duiker Fontein). It is the uppermost portion of the second sheet under the Roggeveld escarpment. In a hand specimen it is dull white or grey in colour, rather like a hard white sandstone. Under the microscope (Slide No. 1066) little of the original constituents is visible, but the general appearance of the rock is just like that of a dolerite without ophitic structure. The long lath-shaped sections representing felspar are made up of a mixture of weakly polarizing substances, one of which is isotropic, but portions of felspar still remain at places. There is no augite left; it has been replaced by aggregates of sericitic and chloritic minerals, quartz, and some other substances. The original iron ore is still present.

Such "white traps" are known in other countries where dolerite traverses carbonaceous shales or coals. The bleaching of the dolerite must be due to the action of the vapours set free as an effect of the melted dolerite on the damp carbonaceous shales, but the process has not been fully explained. It is remarkable that "white traps" are rare in the coal-bearing beds of the Stormberg Series, although these are frequently penetrated by dykes and sheets of dolerite.

VOLCANIC PIPES OF SUTHERLAND.

There are several localities not far from the village of Sutherland where rocks of a peculiar type occur in more or less circular patches and in dyke-like outcrops. The pipes resemble very closely the Kimberley diamond pipes in their general form and in their relation to the surrounding rocks, and some of them contain breccias similar in general character to the diamond-bearing blue-ground of Kimberley, although there are considerable differences in detail. The closest resemblance is to the breccia-filled pipe of Balmoral (Ratel Fontein), in the Fraserburg Division.*

The most interesting point in connection with the Sutherland pipes is the occurrence of melilite-basalt in close association with them, filling some and forming a dyke-like mass round one group. Some of the melilite-basalt has a close resemblance to the melilite-basalt of Spiegel River, in the Riversdale Division,* which was hitherto the only known example of that type of rock in the Colony. Cohen has described a melilite-augite rock from the Transvaal, which is of quite a different type from those of the Cape Colony.†

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* Ann. Report Geol. Commission for 1900 (pp. 60 and 61).

When the melilite-basalt of Spiegel River was first found the opinion was expressed that it filled a volcanic neck, and the Sutherland outcrops not only strongly support that view, but connect the Spiegel River pipe with those of Kimberley and other places, thus affording a further clue to the age of the whole group of South African pipes outside the Stormberg volcanic area. The Sutherland pipes go a long way towards fulfilling the expectation of the late Professor Carvill Lewis, who was confident that a melilite rock was closely connected with the original form of the Kimberley blue-ground.‡

Before discussing further the significance of the pipes, it will be convenient to describe them and the rocks associated with them. They chiefly occur in two groups, those of the Sutherland Commonage and those of Saltpetre-Kop respectively; but there are others on the farm Matjes Fontein, Blaauw-Blommetjes Keep, Portugal's River, and De Vrede, all in the Sutherland Division.

The ground west of Sutherland village is flat for some 600 yards, rising beyond to a low escarpment of sandstone belonging to the Beaufort Series. This escarpment is breached by a stream from the west, but the gap is now closed by a wall to retain the water. The Powder Magazine stands on the edge of the escarpment. To the west the ground rises gradually towards the Vyf Fontein hills, formed of sandstone and a thick dolerite sheet. The group of volcanic rocks partially occupies the terrace between the low escarpment and the Vyf Fontein hills, and is shown on the accompanying plan.

There are at least eight distinct areas of volcanic rock, but they differ very considerably in nature. The exact form of the various masses is uncertain ,and in the map the continuous lines on the boundaries represent the known parts and the broken lines the uncertain portion.

The roughly triangular area marked No. 1 on the plan mainly consists of a grey compact rock containing irregularly shaped pieces of ilmenite up to an inch in length, broken and more or less well-formed crystals of olivine up to half an inch long, and variously shaped fragments of hardened shale; small irregular cracks in the rock are filled in with a mixture of white minerals, partly calcite and partly one of the zeolites. The specific gravity of a fresh specimen of considerable size (200 grms.) and free from large fragments of ilmenite is 3·11. Under the microscope (994 and 995*) the compact matrix is seen to consist of slightly doubly-refracting fibrous aggregates of a mineral that appears to be a devitrification product, enclosing very pale coloured biotite, melilite, perofskite, apatite, magnetite or ilmenite, and irregular grains of olivine; augite is present in small quantities in the ground-mass. The porphyritic crystals of olivine are corroded and surrounded by small crystals of magnetite and perofskite. The melilite occurs in colourless lath-shaped sections as a rule, but irregular patches of an almost isotropic mineral are evidently sections of melilite nearly parallel to the basal plane. In the lath-shaped sections one cleavage crack is usually seen, and the boundaries of the laths are generally rather irregular, for the surrounding grains project into the melilite for a short distance; the characteristic "peg-structure," striations perpendicular to the base, is not so well seen in the melilite from these rocks as in that from Spiegel River or Matjes Fontein, but it is visible in some sections. It is decomposed by dilute hydrochloric acid with the formation of gelatinous silica, and this reaction is also readily given by the fibrous mineral of the ground-mass. The olivine rarely encloses the other minerals, and most of the apparent enclosures are probably inlets due to corrosion. The mica encloses apatite, magnetite, and perofskite crystals, as well as small patches of the ground-mass. The rock was evidently glassy when fresh.

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* Ann. Report Geol. Commission for 1898 (p. 62).

† Melilithaugitgestein und calcitführender, Aplit aus Süd-Afrika. Tschermak's Min. u. petrogr, Mitth. XIV. (Heft 2).

‡ The Genesis and Matrix of the Diamond (p. 49).

At many of the outcrops in the triangular area the rock is quite fresh-looking beneath a thin outer crust, which is less than ½ inch thick, but in other places it has weathered to a depth of 80 feet from the surface. There is even a difficulty in deciding whether some of the weathered rock is derived from the decomposition of the melilite-basalt or whether it is a tuff. The weathered rock is yellowish in colour, and contains lumps of ilmenite and irregular olivine crystals similar to those found in the unweathered rock. On the south-west side of the area there is a distinct breccia, consisting chiefly of fragments of sedimentary rocks in a bluish-grey sandy matrix. Near this breccia, but further from the wall of the pipe, there is a grey tuff containing numerous flakes of mica, which are visible to the naked eye. Examined under the microscope, this rock is found to consist of grains of quartz, flakes of brown mica, broken crystals of olivine, augite, brown hornblende, and some felspar, set in a matrix of dusty material with much calcite. The iron ores and perofskite are scarce; the latter mineral only occurs surrounding some pseudomorphs of serpentine after olivine, and is itself in part changed to a quite opaque substance. Much of the olivine is serpentinised, and with the serpentine there are patches of a bright blue mineral, that appears to be a part of the serpentine, which is usually of a greenish colour in thin sections; the blue mineral is almost isotropic in the interior of the areas bounded by cleavage cracks, but shows low polarization colours along the cracks just as the normal serpentine pseudomorphs do.

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* The numbers within brackets refer to the slides in the Survey collection.

There can be no doubt that this tuff is a mixture of fragments derived from sedimentary beds and from an igneous rock similar to, but not identical with, the melilite rock previously described. The rarity of perofskite and ilmenite, the differences in the biotite of the two rocks—a much paler and less pleochroic mineral occurs in the melilite rock than in the ash—distinguish the ash from the melilite-basalt; and the presence of augite in fairly good crystals, and the deeply coloured brown hornblende in the ash give it a similarity to the breccia of Silver Dam (Matjes Fontein).

It is only along the south-western portion of the neck that the contact with the surrounding sedimentaries can be seen; elsewhere it is hidden by soil and sand. The thin sandstones and shales are distinctly hardened near the pipe, and in places have a well-developed columnar structure; the columns range from 12—14 inches in diameter, with their axes directed away from the pipe, but in some cases they are curiously curved and arranged in radiating groups. Portions of ashy material have been forced in between the beds of sandstone to a distance of a few feet from the pipe. The sandstones dip away from the pipe at various angles up to 20°, but in this area the outward dip is not nearly so pronounced as in the case of the beds round the Saltpetre Kop pipes; on Sutherland Commonage the outward dip is only noticeable a few feet from the pipes.

A shaft 80 feet deep has been sunk in the No. 1 area, but it is now mostly filled in with debris from the sides. The shaft, according to information given us by Mr. J. Kennedy, of Sutherland, did not reach any other material than that seen near the surface, which is a soft blue-grey ash. There can be no doubt that this triangular area is a pipe, and that the ash and melilite-basalt continue far down below the surface.

No. II. area is a curved outcrop of melilite-basalt about a mile and a quarter long, and at the most 350 feet wide; but at the western end it forks, and the width across the ends of the branches is some 700 feet. The outcrop diminishes greatly on the eastern side, being only a few feet wide near the low sandstone escarpment on which the Powder Magazine is built. The surrounding sandstones dip away from the outcrop of melilite-basalt on either side of it in its south-eastern part, but on the north and west this is not the case, the beds dipping away from it on one side only. No tuff or ashy material has been

observed in this area; it has the general characters of a curved dyke, and as can be at once seen on the plan, it encloses the smaller areas which are certainly pipes. There was no evidence to show that this long outcrop is a sheet, and the supposition that it is a dyke agrees well with the observed facts.

The rock has a very similar appearance to that of No. I. area, but contains rather more zeolitic minerals, which appear as white flecks filling irregularly shaped cavities, and the ground-mass breaks with a less smooth fracture. Under the microscope, there are many points of resemblance between the two rocks. The specimens from No. II. contain fine crystals of olivine, of which the larger are often corroded but otherwise little altered in substance; the very pale coloured biotite is abundant; melilite is present in all of the slides, but is usually altered. The partly altered melilite is easily recognisable, for the alteration proceeds along the striations of the peg-structure, giving rise to long jagged laths; the altered mineral substance is fibrous and polarises rather brightly when the fibres lie parallel to one another. The wholly altered mineral seems indistinguishable from the general ground-mass which is largely composed of matted fibres. Perofskite and magnetite or ilmenite are always present. Augite is abundant, which is a point of distinction from the No. I. rock, that contains very little augite. The rock varies in the amount of melilite, augite, and mica present at different points in the course of its long outcrop, but there is no rock in it essentially different from that described.

Included within the No. II. area are some large mases of baked shale and grit many feet in length. These are evidently pieces of the wall broken off, and now surrounded by the igneous rock. Small pieces of the sedimentary rocks are in places rather abundant in the dyke.

No. III. area is an irregularly shaped mass of melilite-basalt. In appearance this rock is like that of the melilite-basalt of Nos. I. and II. Under the microscope, it is seen to contain more melilite than either of the others, but no pale biotite is visible; minute granular areas may be augite, but there is no clearly defined occurrence of that mineral; olivine in good crystals but often corroded is present in large quantities, and perofskite and magnetite are abundant. There are inclusions of an earlier consolidated melilite-basalt in this rock, and these inclusions contain a pale biotite like that of the other outcrops, and rather more melilite than is usually present. A rough flow-structure is visible in this rock, due to the arrangement of the small melilite crystals more or less parallel to one another, especially in the neighbourhood of the large olivines, round which they have a stream-like disposition.

No. IV. is an elliptical area of melilite-basalt, about 300 feet long by less than 100 wide. No conclusive evidence was found as to the nature of Nos. III. and IV., but they are probably pipes.

The remaining outcrops of volcanic rock on Sutherland Commonage are of quite a different nature from those hitherto described. No melilite-basalt has been noticed in them, and they consist of altered vesicular lavas.

Owing to the general covering of soil and blocks of sandstone and dolerite washed down from the steep escarpment to the west, the areas marked Nos. V.—VIII. are badly defined on the ground, and the boundaries marked on the plan are diagrammatic. There is, however, no doubt of the separation of Nos. V. and VIII., and of these from Nos. VI. and VII.

The rocks in these vents, so far as they can be seen at the surface, vary considerably in the amount of weathering they have undergone, and also in the quantity of sandy materials contained in them. When fairly fresh the rocks have a dark glassy appearance and are sometimes banded. They are all more or less vesicular, some being quite scoriaceous. The vesicles are mostly filled with various minerals, natrolite, analcite, and calcite amongst others. Quartz does not appear to be present in any form, except as sand grains derived from the surrounding sedimentary rocks.

The only large porphyritic constituent is olivine, which is now replaced by serpentine (1038). The serpentine pseudomorphs are usually accompanied by a greatly altered fine-grained rock adhering to them as though the olivine belonged originally to this rock and not to the glassy material now enclosing it.

The glass is in some specimens (1037-1038) quite fresh and isotropic; in it lie minute needles of a doubly refracting mineral that has not been determined; another mineral, also undetermined, occurs in very minute rectangular and hexagonal sections, that show double refraction and straight extinction; they are frequently altered to a greenish-yellow mass of granules.* Augite is probably present in very minute columns, some of which are large enough to show a high extinction angle (35°); much magnetite in very small fragments and crystals, grains of quartz, angular and rounded, and similarly shaped grains of felspar are frequently seen, especially in the more gritty rocks, but the quartz fragments are recognisable in the most glassy lavas. No recognisable felspar laths are seen in the glass.

The lavas sometimes contain large blocks of sandstone, with cavities filled in by zeolitic minerals.

The outcrops on the Sutherland Commonage may be looked upon as a group of vents surrounded on two sides by the curved dyke of melilite-basalt marked No. 2 in the plan.

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* The mineral resembles nepheline in optical characters, but refuses to give the chemical reactions characteristic of that mineral.

There is no evidence to show the precise relationship of the glassy lavas in Nos. V.—VIII. to the melilite-basalt of the other outcrops, but from the fact that the glass is evidently highly basic and contains large porphyritic crystals of olivine, to which still adhere a ground-mass that may well be an altered rock of the melilite-basalt type, it seems likely that the glassy lava filled the pipes after the melilite-basalt was injected. The presence of tuff in both classes of pipe appears to prove that the vents were for a time at least open to the air, and that they were partially filled with tuff or agglomerate before being finally plugged up with the igneous rocks that crop out at the present surface. The scoriaceous glassy lavas must have contained more water in the form of steam than the melilite-basalt, which is not amygdaloidal.

No inclusions of dolerite have been found in these vents, although dolerite is abundant just to the north and west of them. Very probably the vents do not pierce a dolerite sheet, as the lowest sheet in the neighbourhood lies at a slightly higher horizon than the present outcrop of the rocks filling the vents. In this respect the Sutherland Commonage pipes differ from those to the south-east to be described presently. It must be remembered, however, that the outcrops are often very meagre, especially those of the agglomerates, and it is quite possible that better exposures will yield positive evidence on this point.

About three-quarters of a mile south-south-east of the homestead on Matjes Fontein there is a pipe, in which two shallow pits have been sunk for prospecting purposes. The exact size of the pipe is uncertain, on account of the general covering of deep soil.

The surrounding rock is exposed in one of the pits and in a few outcrops in the neighbourhood; it is a greenish sandy shale, dipping at a high angle away from the pipe, as can be seen in the pit. The agglomerate contains sub-angular, angular, and rounded boulders of various rocks up to 3 feet in diameter, imbedded in a yellowish-brown earthy material, rather gritty when rubbed between one's fingers. The included fragments are mainly pieces of shale and sandstone that were probably derived from the rock forming the walls of the pipe at no great depth from the surface, as they resemble closely many beds in the Beaufort Series. Large fragments of granite and gneiss are present; much decomposed plates of black mica up to an inch in diameter, ilmenite, and irregularly shaped fragments of lustrous black hornblende up to three inches in length are scattered through the matrix. The black hornblende is considerably shattered by the weather, but it is of the same nature as the better preserved specimens obtained at the Silver Dam shafts on the same farm.

From the second shaft, about 25 feet from the one just mentioned, a melilite-basalt of peculiar character has been exposed. There is no section showing the junction of this rock with the breccia, but there can be little doubt that it occurs within the same pipe, just as the melilite-basalt of Sutherland Commonage is associated with the tuff in pipe No. I. of the plan.

The Matjes Fontein melilite-basalt appears to be considerably altered, for it effervesces freely with dilute acid, owing to the amount of calcite present in minute grains. Its specific gravity is 2·77. In a hand specimen the rock is dull greenish-black in colour, with large crystals of mica up to ½ an inch in diameter, which are rather decomposed in the specimens we obtained. Small green crystals of olivine are conspicuous on a freshly broken surface; they do not reach a greater length than about 1 mm. Under the microscope the rock is seen to consist of well-developed porphyritic olivines lying in a ground-mass of melilite, brown mica, perofskite, magnetite, and interstitial matter, which is largely composed of serpentine-like fibres and calcite. No glass is present, but the fibrous minerals in the ground-mass may represent it. No augite has been seen in the rock. The olivine is occasionally altered into serpentine along cleavage cracks, and encloses patches of the ground-mass, flakes of mica, and crystals of magnetite, but melilite and perofskite do not seem to be included by it. Both the magnetite and perofskite are often arranged as a border to the olivine sections. The mica is rather strongly pleochroic, but differs from the biotite in the Sutherland melilite-basalt as well as from all ordinary varieties of biotite, in showing the greatest absorption when the short diagonal of the Nicol is perpendicular to the trace of the cleavage in transverse sections. Melilite is very abundant in lath-shaped sections arranged roughly parallel to one another and to the long axes of many of the olivine crystals, thus giving the rock a distinct flow-structure. The crystals are tabular, about 0.1 mm. wide and a tenth of that amount in thickness. It is colourless or very slightly tinted yellowish-pink. The peg-structure is often well developed. It is quickly attacked by hydrochloric acid, and the resulting gelatinous silica can be deeply stained with fuchsine. In the character of its double refraction, which is positive, it differs from the melilite in the Sutherland Commonage rock and that in the Spiegel River melilite-basalt. Calcite is very abundant in the ground-mass, occurring in minute irregular grains. It is difficult to understand where so much calcite comes from, as the melilite is remarkably fresh, the olivine has given rise to very little if any magnesium carbonate, and the surrounding rocks are but slightly calcareous.

Within the same pipe there is an outcrop of dolerite several feet in diameter. There is no distinct evidence as to the relation of the dolerite to the pipe, whether it is a boulder or an intrusion. The rock is very coarse ophitic olivine-dolerite, such as is usually met with in the thicker sheets and dykes. In the Silver Dam pipe and those of Saltpetre Kop fragments of dolerite are not uncommon in the breccias, so it is very probable that this outcrop is only a large inclusion in the breccia of the Matjes Fontein pipe.

No analyses of the Sutherland Commonage melilite-basalt or of the Matjes Fontein rock have been made, but it is desirable to publish here the results of an analysis of the Spiegel River melilite-basalt recently made by Mr. J. Lewis, B.A., Government Analyst. The specific gravity is 3.205, and the chemical composition as follows:—

SiO_2	36.15
TiO_2	2.30
Al_2O_3	15.18
Fe_2O_3	4.87
Cr_2O_3	.10
FeO	9.11*
MnO	.33
CaO	11.40
MgO	13.63
BaO	.06
Na_2O	2.42
K_2O	1.81
P_2O_5	.26
SO_2	.49
H_2O on ignition	1.95
H_2O driven off below 110° C.	.37
	100.43

The low figure for the water and the absence of carbonates proves that the rock has undergone very little alteration since its solidification, a fact that is fully supported by a microscopical examination of the rock. This rock was briefly described in the Annual Report for 1898, p. 62, but a description may be given here for comparison with the Sutherland examples. In a hand specimen it is a heavy compact dark grey rock with numerous olivine crystals about 1 mm. in length. Under the microscope the olivine is seen to be very fresh, with only a slight amount of serpentine in a few irregular cracks. It appears to enclose patches of the ground-mass, which is sometimes glassy; crystals of melilite, perofskite, and magnetite, and small grains of augite, are included in these patches, which probably fill corrosion cavities.

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* A little sulphide which would slightly increase the figure for ferrous iron is included. The sulpur present as sulphide is included in the SO_2.

Magnetite is occasionally enclosed by the olivine, but perofskite and the other constituents of the ground-mass are never seen in the olivine except as part of the contents of a large cavity.

Melilite is the most conspicuous constituent after the olivine. It is usually in lath-shaped sections up to 0.2 mm. in length; it shows the peg-structure well, and each lath has usually one cleavage crack parallel to its length. The mineral is readily attacked by hydrochloric acid, and the gelatinous silica that is left on the surface can be stained with the usual aniline dyes. In optical character it is negative.

Augite is present in irregular grains and in very small imperfect crystals. It is distinguished by its strong refraction, and high double refraction, and extinction angles of 35°—40° with the length of the crystallites. It is very pale green in colour.

Magnetite and perofskite are abundant.

There are some small rectangular sections in parts of the slices from this rock that escaped notice previously. They have low double refraction and straight extinction, and a rather low refractive index, standing out less strongly than the melilite. Hexagonical sections belonging to this mineral are isotropic. It is probably nepheline, but its nature has not been tested chemically.

No biotite occurs in this rock.

The results of the analysis of the Spiegel River rock bears a general resemblance to those of the melilite-basalts quoted by Zirkel in Vol. III., p. 71, of his "Lehrbuch," 2nd edition, 1893, but they are not coincident with any one of these.

The rocks from these localities, Sutherland Commonage, Matjes Fontein, and Spiegel River, are by no means identical, each has important characters that separate it from the other two types. In the Commonage rock there is little augite, and the melilite is less abundant than in the other two. The Matjes Fontein rock has melilite with positive double refraction and brown mica with anomalous pleochroism, and contains no augite. The Spiegel River rock has no biotite but an abundance of augite. Notwithstanding these differences there are strong points of resemblance, and the rocks occur in a similar manner, filling, or partially filling, pipes or volcanic chimneys. Melilite-basalt is a peculiar and unusual type of rock, and in the case of the three known occurrences in Cape Colony there are good grounds for the assumption that they belong to the same period of igneous activity. The Commonage and Matjes Fontein pipes are certainly younger than the Beaufort Series, and the Spiegel River pipe is younger than the Uitenhage Series, so that if the vents containing melilite-basalt can justly be regarded as of the same age, then the Sutherland pipes are later in age than the Uitenhage Beds.

We have seen that Professor Carvill Lewis considered that the mineral constituents in the matrix of the Kimberley blue-ground was derived from melilite-basalt, but he did not find any melilite amongst his specimens. The association of the Matjes Fontein rock with a breccia, which although most certainly not identical with the Kimberley breccia, is evidently a rock formed by the same means, and contains some minerals, mica and ilmenite, for instance, which are identical with those from Kimberley, affords a connecting link between the two groups of pipes. The Silver Dam pipe on the same farm, Matjes Fontein, has in its mineral contents a much greater resemblance to the Kimberley rock than those hitherto mentioned, and decidedly supports the grouping together of all those volcanic phenomena from Kimberley to Spiegel River in one class, probably formed at about the same time.

The Silver Dam pipe lies a little over a mile to the north-east of the Matjes Fontein pipe containing melilite-basalt Part of the pipe is marked on the surface by a pan-like depression. The rock in the pipe does not crop out at the surface, so that the actual junction with the surrounding shales and thin sandstones of the Beaufort Series is not seen. The diameter of the pipe is about 180 feet. Two prospecting shafts have been sunk in it, one within the pan and the second just outside it. In each case most interesting breccias were obtained, but no igneous rock of the type of the melilite-basalt of Matjes Fontein or the Commonage.

The following descriptions of the Silver Dam rocks are based upon specimens obtained from the shafts by the prospector and left piled up round the top of the shafts. The shafts themselves are of considerable depth, and partly filled with water, and there is no means of going down them now.

The rock from the shaft (south-west) within the depression is much softer than that from the other pit (north-east). The former in a hand specimen appears to be a bluish-grey mudstone crowded with fragments of several varieties of rocks and minerals. Amongst the rocks are granulites, shale, sandstone, quartzite, dolerite of the Karroo type, and some peculiar heavy rocks made up entirely of ferro-magnesian minerals. Amongst the minerals recognisable without special aids are biotite, hornblende, augite, and ilmenite. Calcite is very abundant in the matrix, which effervesces freely with dilute acid.

Under the microscope the matrix is revealed as a mass of grains or large areas of calcite, in which are crystals of perofskite, grains of iron ore, fibres of a serpentinous mineral, and other substances too indefinite in form and character to be determined, but some of which are probably comminuted sedimentary rock. (1011, 1012, 1013, and 1014.) The matrix is evidently considerably altered, but whether it is mostly derived from igneous or sedimentary rocks is difficult to decide, though the abundance of perofskite and iron ores points to much of it having been derived from an igneous rock. There can be no doubt that it is an agglomerate and not a lava containing many inclusions.

In addition to the constituents of the matrix just mentioned there are small fragments of pyroxene, hornblende, mica, and ilmenite similar in other respects than size to the larger lumps of those minerals present in the rock.

The minerals that have been recognised in fair sized fragments are the following:—

Olivine crystals entirely replaced by serpentine. No fresh olivine is visible. Pyroxene of four varieties: (1) Colourless, with very well developed cleavages, occasionally in crystals with good faces, but usually broken fragments; this mineral comes from a rock that is fairly abundant in the form of inclusions in the pipe. (2) Colourless, with many diallagic inclusions, and less well developed cleavages than (1); it is derived from the olivine dolerites of the Karroo type, and often encloses crystals of felspar ophitically. (3) A very pale green pyroxene with distinct though very slight pleochroism, derived from a rock represented by many fragments in the breccia. (4) A more brilliant green variety, more strongly pleochroic than (3), identical with the augite in a granulitic rock present in large fragments. Hornblende in large fragments, brown, and moderately pleochroic; it shows the characteristic cleavages, and occurs in conjunction with ilmenite and biotite. It is derived from a basic rock abundant as fragments in the breccia. Mica is present as large and small flakes. It is a biotite with rather weak pleochroism. Another variety with strong pleochroism is also present. The mica, hornblende, and augite fragments are usually altered on their outer borders; they are somewhat bleached in that zone, and contain numerous dusty inclusions. Apatite and garnet are in small irregular grains. Felspar in a much altered condition is rather abundant as small broken grains. In addition to fragments of shale, sandstone, quartzite, and dolerite of the Karroo type, there are subangular lumps of peculiar granulitic rocks in the breccia. There are three main types of these rocks. (1) A dark coloured rock with many garnets visible to the naked eye. Specific gravity 3.15; under the microscope the constituents are seen to be a very basic plagioclase in clear grains, a very pale green almost colourless augite, brown hornblende with weak pleochroism sometimes grown parallel with the augite but more usually as independent grains, pale garnets always surrounded by a dark, almost opaque rim of alteration products (the so-called kelyphite rim) and ilmenite. The contact of felspar grains with one another or with the other minerals is always marked by a narrow zone of alteration products of which calcite is one. The structure of this rock is distinctly granulitic. Although unlike any rock known *in situ* in the Colony it has a resemblance to some of the Prieska granulites in the nature of the augite. The brown hornblende of this rock has not been seen in any of the Prieska specimens. (1017.)

(2) A black rock (specific gravity 3.23) composed of pale green slightly pleochroic augite, strongly coloured brown hornblende with strong pleochroism, strongly pleochroic brown mica, ilmenite, calcite filling up sharply defined cavities within the crystals of augite, mica, and ilmenite; apatite is present in small quantities, and there is also a cloudy alteration product filling spaces between the other constituents, and penetrated by very fine needles of a doubly refracting mineral. No felspar is visible. (1020.) Between these two types there are transition varieties represented in the comparativly small collection of these rocks obtained from the south-western shaft. The second type grades into the first by an increase of the augite, which becomes less highly coloured, by the decrease in the colour of the hornblende, and by the increase of felspar and garnet. Some specimens are rich in apatite. The minerals tend to form aggregates; thus one-half of a slice (1021) may consist of augite alone, while hornblende is very abundant in the other half, or a whole slice (1020) may be composed of augite. These rocks are certainly of a very unusual type, especially the extremely basic variety (No. 2), which is quite unlike any rock known in place from South Africa. They are allied to the rather indefinite group of basic rocks called eclogites.

(3) A banded granulitic rock consisting of white and black grains roughly arranged in layers. Under the microscope the apparently black grains are seen to be brilliantly green coloured augite (chrome-diopside) distinctly pleochroic; these grains and apatite are imbedded in a cloudy mass of altered felspar. No other constituents have been noticed. The edges of the chrome-diopside grains are altered somewhat, being thickly set with opaque dusty matter. This rock is not known *in situ* in the Colony, but is evidently related to those just described.

The breccia from the north-eastern shaft on Silver Dam is considerably harder and less serpentinous than that from the other pit. The matrix is grey, and contains much calcite. Angular fragments of shale, sandstone, and quartzite are abundant, more so than in the other rock; small pieces of augite, hornblende, mica, and ilmenite are very conspicuous, owing to their black colour and bright surfaces, but they are generally in smaller fragments than the same minerals in the softer rock, and fragments of granulite and the augite rocks are much less frequent and in smaller pieces. Under the microscope calcite and small crystals and fragments of ilmenite are conspicuous, but there are also many quartz-grains, probably derived from comminuted sediments. Perofskite can be found without difficulty, but it is not very abundant. The augite, mica, hornblende, and ilmenite are similar to those previously described from the south-western shaft, but the green augites are rare. Serpentinous pseudomorphs after olivine are present. (1008, 1009, 1010.)

The only rock-fragment of igneous origin, excluding the individual minerals just mentioned, noticed in the slices, is an ophitic dolerite of the Karroo type. Nearly all the included fragments, whether of simple minerals or of rocks, are outlined by a narrow band of somewhat altered material.

The breccias from the Silver Dam shafts have a distinct resemblance to the serpentinous breccia of the Kimberley pipes. A comparison of the rocks from the two districts shows that the chief difference is in the less amount of serpentine in the Silver Dam rock. The orthorhombic pyroxene, usually said to characterise the Kimberley blue-ground,* has not been observed in the Silver Dam rock, but the mica, ilmenite, green augite, perofskite and olivine are similar. In each case the brown mica is but slightly pleochroic in many specimens. Orthite, smaragdite, tourmaline, epidote, and diamond, minerals that occur more or less sparsely in the Kimberley blue-ground, have not been found at Silver Dam. The same alteration zone round many of the inclusions is seen in specimens from both localities.

The ground-mass of the Kimberley breccia and that from the south-east pit at Silver Dam are very similar; it is probable that the pipes at those localities, as well as the Matjes Fontein and some of the Sutherland Commonage vents, were partly filled with agglomerate, of which the matrix was mainly derived from a melilite-basalt or allied rock, and that the included rock fragments and minerals varied according to the nature of rocks through which the chimney was blown. On this view the perofskite, much of the ilmenite and olivine, and the very slightly pleochroic mica belong to the melilite-basalt or allied peridotite, which was the actual molten rock of the eruption. The augites, hornblende, garnets and other minerals belonged originally to more or less deep-seated rocks, which were not necessarily products of the magma that gave rise to the melilite-basalt; the fragments of these rocks were carried up by the explosion and imbedded in the matrix of the agglomerate.

This view is the same in many respects as that put forward by Professor Bonney,† who described diamonds imbedded in a lump of eclogite from the Newlands Mine, Griqualand West.

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* See foot-note by Prof. Bonney on p. 19 of Carvill Lewis' book quoted on a previous page.

† T. G. Bonney, Geol. Mag., 1899 (pp. 309–321). Also Geol. Mag., 1900 (pp. 246–248).

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The eclogite is mainly composed of pyrope (garnet) and chrome-diopside, and though evidently not identical with the fragments of augitic rocks just described from Silver Dam, it is not very different in nature from them. Related rocks from the blue-ground of the Monastery Mine (1090, 1091, 1093, 1094) contains enstatite in addition to the chrome-diopside and a colourless augite. No outcrop of rocks exactly of this nature are yet known in the great areas of crystalline rocks in the north of the Colony.

In the Saltpetre Kop group there are many peculiar features not seen in the pipes previously described. There are at least twenty distinct necks within an area of less than three square miles. The similar necks or fissures filled with agglomerates at Blaauw Blommetjes Keep, De Vrede, and Portugal's River lie outside the Saltpetre Kop group, and will be described subsequently.

The highest point of Saltpetre Kop is about 5,500 feet above the sea and 1,100 feet above the bed of the Rogge Kloof River, which traverses the group of vents. This point, called Old Sneeuw Kop on the Divisional Map, forms a centre, about which other prominent kops are scattered irregularly, as shown on the accompanying plan. The central peak is a rugged, precipitous mass of agglomerate, the most conspicuous object in the landscape for many miles round. From any point within four or five miles of the high peak the sedimentary rocks (Beaufort Beds) are seen to dip away from the central peak in a remarkably regular manner; the angle of dip decreases along any one radius from 45° and higher near the kop to 10° at the distance of a mile. There are, of course, some irregularities noticed when the ground is traversed closely, but these do not affect the qua-quaversal dip as a whole. The dip is not appreciably influenced by the minor necks that pierce the rocks surrounding the main vent.

Looking from the top of Saltpetre Kop one sees in every direction the steep faces of curved escarpments defined by the outcrops of the thicker sandstones. The most continuous of these are the one on Blaauw Blommetjes Keep and the dolerite-capped ridge to the west of Rogge Kloof River. The others are considerably broken up by the tributaries of Portugal's River, but each segment maintains the characteristic features of the whole.

The largest neck (No. I.) measures roughly 3,000 x 1,700 feet, but the precise position of the boundary cannot be laid down in every part of its course on account of its concealment under fallen débris on the west of the kop, and under stream-deposits on the east. The neck is certainly constricted in the middle. The highest point is on the northern half, which is connected with the southern by a ridge of high ground crowned by a peak,

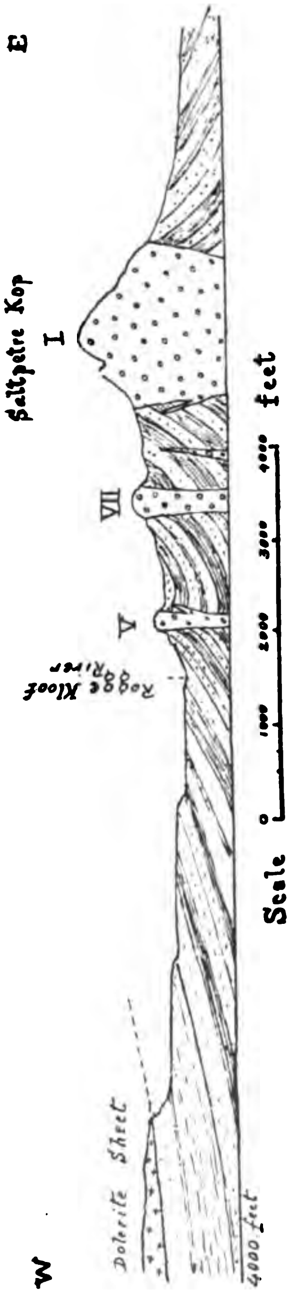

FIG. 2. – Section across Saltpetre Kop.

marked No. VIII. on the plan. In the north and west portions of this vent the rocks are hard agglomerates, with finer grained masses in them. The agglomerate varies greatly in appearance within a few yards by the increase or decrease in the quantity of oxides of iron in the rock, but, as a rule, the coarser varieties contain less ferric oxide than the finer, and the proportion of iron compounds is greater near the walls of the vent than in the interior. The less ferruginous portions of the higher peak are, in fact, red argillaceous-looking rocks, containing many small angular pieces of shale, mudstone, and sandstone; only one fragment of a mineral which is conspicuous in the Silver Dam pipe is visible in the specimens from this rock; it is a small piece of ilmenite. Other portions of the highest peak are made of a very siliceous rock; it is brownish in colour and cavernous, the spaces being irregular in form and often lined with quartz crystals. The angular fragments are of sandstone, shale, quartz, blue-grey breccia, and felspar, much weathered but probably orthoclase. Under the microscope no further original constituents have been determined, except small grains of microcline (1027) Dolerite boulders occur in the western part of the agglomerate of this neck. The rock has certainly been hardened by the addition of new silica in the form of a minute mosaic between the original constituents. In general appearance and in microscopical characters this rock is very much like some of the surface quartzites, and the similarity is due to the silicification of a breccia in each case. It would be very difficult to distinguish parts of the Saltpetre Kop rock from the surface quartzite on the evidence of a hand-specimen alone. Fresh felspar is foreign to the surface quartzites, but from parts of the Saltpetre Kop breccia it is also absent. No two fragmental rocks could well have had more different origins than these, and the close resemblance is, so to speak, quite accidental.

Towards the south-west the material in No. I pipe becomes much less coarse, and at the same time highly ferruginous (specific gravity of an average ferruginous specimen is 3·4). In a hand-specimen the extreme type of this rock is black, and it is without visible inclusions. Under the microscope it is seen to consist of a quartz mosaic and iron ores, partly opaque and partly in deep red semi-opaque masses; the iron oxide is mostly in the form of limonite. Every stage between a rock of this type and the coarse breccias can be found on the western side of the pipe.

The hard silicified and ferruginous rocks are traversed by many fissures partly filled with barytes, of which good crystals may be obtained. The barytes seems to be confined to the central vent of the Saltpetre Kop group.

In the valley south of the main peak, near the southern of the two shafts marked on the plan, there is an outcrop of a hard cherty rock containing many small fragments of shale and quartzite; it is a dark grey compact rock, and weathers brown and yellow. Under the microscope the most conspicuous constituent is a carbonate, with strong double refraction, probably dolomite, as it is not attacked by dilute acid. The dolomite makes up a considerable portion of the rock, as it is present both in the ground-mass and as fragments, as well as in cavities and cracks in the shale fragments. Other rocks in this valley are quite soft, and are now brown or yellow materials, containing shale and quartzite fragments and flakes of brown mica, chips of hornblende, and ilmenite. This rock is distinctly bedded, although the dip of the beds varies within short distances. At one spot it dips vertically, and strikes east and west, six feet away it dips 45° to the north-east. At some places this soft tuff has been impregnated with hydrated oxides of iron and approaches in character the ferruginous rock on the west side of the vent. Some radiating crystalline masses of barytes occur in the soft tuff, probably filling irregular cracks. Thin layers of the same mineral were found in joints.

The probable relations of the large Saltpetre Kop neck to the surrounding Beaufort Beds is shewn in the accompanying section. (Fig. 2.) The greatest difference in level of the contact at various spots is about 500 feet, and there can be no doubt that the whole mass occupies a pipe of the nature of that shown in the section.

The qua-qua-versal dip of the strata on all sides proves that an immense force must have been exerted in a vertical direction before or during the ejection of the débris through the great vent. A similar feature, but on a very much smaller scale, has been observed round the Kimberley pipes and that of Balmoral (Ratel Fontein), Fraserburg, but in all those cases the qua-qua-versal dip affects the rocks to the distance of only a few yards from the boundary of the pipe. The Saltpetre Kop area reminds one immediately of the diagrams illustrating the old " Elevation crater " theory of the formation of volcanic mountains, which has long since been abandoned in the light of the knowledge gained in volcanic areas during last century.

So far as the structure of the whole area is concerned the central neck dominates the others so completely that the minor vents yet to be described might be removed without altering the essential features. Whether evidence of more than one explosion exists in the great vent is uncertain. The coarsest agglomerates are on the northern side, and they are quite without stratification. The finer tuffs on the south-east are bedded irregularly, and may be due to the filling up of the vent by already ejected material falling back again from above.

The present surface features are entirely due to the weather-resisting qualities of the rocks at different part of the area. Each hard siliceous or ferruginous mass of agglomerate stands out on the surface according to its size, and the hard sandstones of the Beaufort Series make prominent escarpments. Any special surface features which may have been produced by the accumulation of débris outside the vent have long since disappeared. The partially radial arrangement of the streams may be due to the original form of the surface, caused in part by the arching up of the strata and in part by the material piled up outside the vent; but it is probably to be explained by the more rapid weathering away of the softer rocks round the hardened agglomerates, for every small neck or ridge of the latter has a direct influence on the course of the small streams near it.

Pipes Nos. II. and III. lie to the north of the central peak, and at considerable distances from it. They are filled with agglomerate containing many inclusions of sandstone and shale.

No. IV. is an agglomerate neck.

No. V. is filled with two kinds of tuff, both fine-grained, with many small angular pieces of shale and fine grit. One variety is a pale yellow rock with a texture like that of a felsite. Under the microscope the ground-mass is seen to be made up of an aggregate of very minute, feebly polarizing, interlocking grains; under a low power it appears isotropic. In it lie fragments of micaceous shales, felspar, and quartz crystals.

(1024.) The second variety is a grey, spotted rock, containing shale fragments and numerous flakes of black mica. Under a high power the ground-mass resolves itself into a substance very like the matrix of the yellow tuff, with the addition of extremely minute brightly polarizing grains or flakes of a micaceous mineral. It encloses fragments of mica, felspar, and quartz, as well as of shale.

Nos. VI., VII., and IX. are agglomerate necks, with no special features of interest.

No. X. is a rather coarse agglomerate, with many rounded and oval pebbles of quartzite of the Table Mountain Sandstone type. Granite and mica-schist, as well as sandstone, grits, and shales, occur as fragments in this pipe. The pebbles just mentioned are rather peculiar; they are covered with slight depressions, as though they had been struck repeatedly by other stones, and they have not got the smooth surface characteristic of water-worn pebbles of this quartzite picked up in streams or gravel beds. The agglomerate is hardened by oxides of iron and silica deposited between the grains.

The granite, mica-schist, and quartzite have been derived from rocks older than the Karroo formation, unless they come from the Dwyka Conglomerate, which is almost certainly present at a depth of some 3,000-4,000 feet below the surface at Saltpetre Kop. Since there is no sure direct evidence as to the depth at which the explosions took place, the source of those fragments must remain problematical, but at Kimberley the volcanic centre lay far below the Dwyka Conglomerate, and it is very probable that the same was the case with the Saltpetre Kop eruptions, as well as with those at Silver Dam, the products of which resemble the Kimberley rocks rather closely.

This vent is oval in section, 90 yards long from north to south, and 45 yards wide. The actual contact with the surrounding Beaufort Beds is not exposed in section, but the dip of these beds can be seen a few yards away from the pipe on all sides of it, and they are all westerly, the appropriate direction of dip for the strata on that side of the great central vent.

Nos. XI.-XX. are agglomerate or tuff necks that do not require individual description. No. XII. contains black mica flakes up to nearly an inch in diameter. Nos. XIV., XVIII., XIX., and XX. form a more definite chain of vents than others of the group, and they are close together. No. XXI. is rather different from those already described in having a considerably softer matrix. It is poorly exposed in the bed of a small stream, a western tributary to the Rogge Kloof River, and the agglomerate is mostly concealed under débris carried down by the river. The fragments in the agglomerate include dolerite of the Karroo type, sandstones and shales from the Karroo formation, and quartzites of the same nature as those of the Table Mountain Series.

The proximity of a neck is nearly always marked in the sedimentary series by the hardening and iron-staining of the sandstones and shales. Beds which contain but small amounts of iron compounds at a distance from these vents become deeply stained in their vicinity, and weather with concentric zones of brown and yellow colours, produced by the various states of hydration and concentration of the iron oxide. Occasionally the rocks are brecciated within a few feet of the pipes, and the fragments are cemented together with oxides of iron and siliceous matter.

In addition to the agglomerate and tuff necks there are 46 dyke-shaped outcrops of hard tuff of much the same nature as the tuffs in the necks, but, as a rule, they are without the large inclusions found in the agglomerates. The longest of these dykes was traced for a distance of rather more than 700 yards, with a maximum width of about 50 feet. The general course of these dykes can be seen on the plan. Many of them run in a north-north-easterly direction, but they do not all follow this course. They were not found to cut through the necks, although five dykes approach the necks very closely, and are probably truncated by the necks. The relationship of these dykes to the surrounding rock seems to be precisely that of basaltic or other dykes of igneous rock to the surrounding beds in a volcanic area. One of the dykes in the group, about 200 feet north of the large central vent, is quite coarse, and consists of angular fragments of white quartzite up to two inches in length, set in a yellowish brown matrix. The long dyke east of necks VII. and IX. is coarse in parts from the presence of angular fragments of quartzite and shale, and it differs in an important respect from any other rock collected in the Saltpetre Kop area; it is largely made up of small, but well-preserved crystals of twinned plagioclase, probably andesine or albite. These lie in a matrix that is very slightly doubly refracting, and is made up of very minute interlocking grains. There is one porphyritic untwinned section of felspar in the slide (1029), and this contains small plates of strongly pleochroic biotite, the only ferro-magnesian mineral in the slice; it occurs in no other form than as these inclusions. A few apatite prisms are present. There is so much calcite in the rock that it behaves with dilute acid like an impure limestone. The calcite occurs in two forms; as minute grains of irregular shape distributed through the matrix, and as large patches, sometimes with sharply defined rectangular outlines, at others with imperfect hexagonal outlines, or with an irregular boundary. No other indications of the mineral replaced by the calcite are to be seen; aggregates of calcite entirely fill the areas enclosed by the straight or irregular boundaries, and there are no chloritic or serpentinous substances within them or in other parts of the slice. The only other constituent is brown hydrated oxide of iron, probably limonite, in irregular grains and masses. It frequently outlines the calcite pseudomorphs as though it had been pushed out of the area by the development of the calcite.

This rock is undoubtedly an igneous one, but the unaltered state of the felspars is out of keeping with the complete replacement by calcite of the unknown constituent. Up to the present time it is the only rock approaching an ordinary igneous one that has been found in the Saltpetre Kop group.

A specimen taken from the dyke running east from pipe No. XII. shows under the microscope a granular mass of limonite, with lath-shaped and irregular patches of calcite aggregates, a few grains of quartz, and fragments of shale and sandstone (1028). A few very small laths of a mineral that may be a felspar are also present.

On the farm De Vrede, at a distance of 2½ miles south-south-west of the central peak of Saltpetre Kop, there are two necks which are of the Saltpetre Kop type. The more northern of the two is filled with a yellow rock, containing large numbers of sandstone and shale fragments as well as quartzites that might have come from the Table Mountain Series. The neck is about 150 feet by 60 in size, and the included fragments are of very considerable dimensions. One block of sandstone exposed in the agglomerate is from the Karroo Beds, and is over 10 feet in length. Some of the quartzite pebbles are well rounded and from two to four inches in length. The rock is very calcareous, but we have at present no slices from this group of necks for the closer determination of the nature of the rock. The smaller neck measures 30 feet by 45, and it is filled with a material similar to that of the larger vent. A narrow, yellow coloured, earthy-looking dyke projects from the larger neck northwards through the Beaufort Beds. This dyke contains barytes and carbonate of lime in considerable quantities, and there are also many large plates of black mica in it. The carbonate of lime is in thin lath-shaped areas, probably pseudomorphing some other mineral.

On the farm Portugal's River there is a long, curved dyke of coarse agglomerate 500 yards long by about 80 in width. It is an iron-stained breccia of sandstone and shale, and it contains both gypsum and calcite. The included sandstone fragments reach five feet in length. The general direction of this dyke is north-west, and its south-eastern end is crossed by the road going down the valley.

On the farm Blaauw Blommetjes Keep, at a locality about 2½ miles north-west from the central vent of the Saltpetre Kop group, there is a most remarkable sheet-like outcrop of agglomerate resembling the Saltpetre Kop rocks. The accompanying plan illustrates the occurrence of the agglomerate and its relation to the surrounding rocks. (See Fig. 3.) Whether the large area marked in the stream bed near

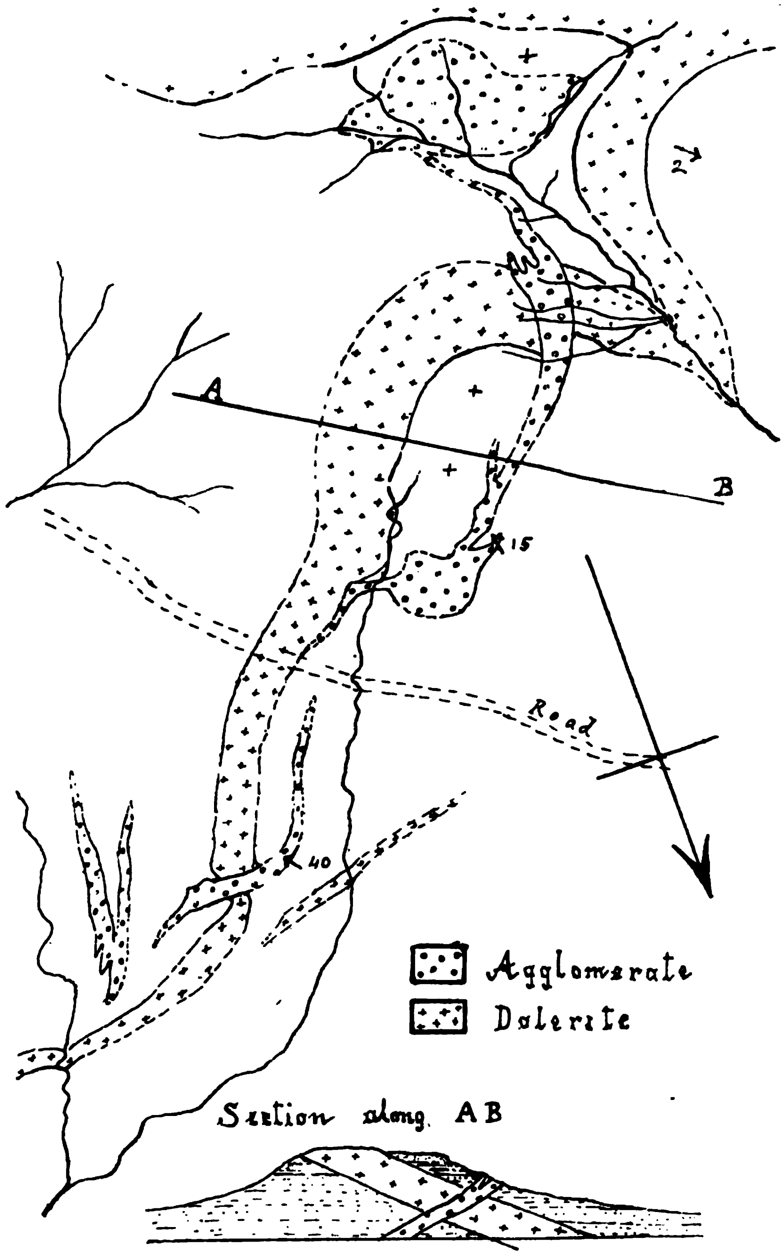

FIG. 3.—Plan of Agglomerate sheet on Blaauw Blommetjes Kop. Length of plan about half a mile.

the south end of the map is a neck is uncertain, but as a vertical thickness of fully 100 feet of agglomerate is exposed between the stream bed and the southern boundary, it may well be a neck. The sheet-like portion to the north is much less thick. The agglomerate in the stream bed gives off a dyke to the northwards, and this dyke becomes nearly horizontal on the northern face of the hill to the north-east of the line of section, A—B. The most important point in connection with this occurrence is the fact that the agglomerate sheet or dyke cuts through a thick sheet of dolerite at two places, which are clearly indicated on the plan. This proves that the agglomerate was posterior to, or later than, the dolerite sheet; a strong confirmation of the evidence afforded by dolerite boulders and fragments in the Saltpetre Kop vents, and in the Matjes Fontein neck.

The rock itself varies considerably in texture and composition. Much of it looks like a decomposed mica-trap, with many inclusions of shale and sandstone; it is very calcareous. Other parts are more compact, heavily charged with iron oxides and calcite, and are deep brown in colour; this rock also contains many small angular fragments of shale and sandstone. On exposed surfaces the compact rock has weathered concentrically within the areas enclosed by two, or sometimes three, sets of joints, and presents a most remarkable appearance. Under the microscope (1034) the calcite is seen to replace some other mineral, and from the outlines of a few pseudomorphs this replaced mineral may have been identical with that mentioned on p. 62 as replaced by calcite in a dyke in the Saltpetre Kop group. In some of the Blaauw Blommetjes Keep rock (1034) there is no felspar or other mineral present that can be regarded as a normal constituent of an igneous rock; and from the absence of other alteration or replacing minerals than calcite and hydrated iron oxides it is impossible to offer a suggestion as to its original nature. It must be remarked that the only specimens obtained which seemed at the time to be suitable for cutting thin sections from were of the compact ferruginous variety.

About three miles east of Sutherland Village there are perhaps some volcanic pipes concealed under the surface soil. Their presence is indicated by fragments of hornblende lying in the surface soil, and in one case by a piece of quartz-porphyry, evidently derived from a breccia of the nature of the Saltpetre Kop rock. A piece of siliceous breccia was also found in this neighbourhood lying upon the surface. There is no other evidence for their existence, but as the pipes of Silver Dam and Matjes Fontein were marked by similar surface indications, there is little doubt concerning these occurrences.

Although the various rocks in the pipes included in the above account are of different natures, they have such striking points of resemblance and connections that we are forced to believe that they belong to one period of volcanic activity.

In the first place, where the pipes are in the immediate neighbourhood of dolerite intrusions they contain evidence of later origin than that of the dolerite. This applies to the Matjes Fontein, Silver Dam, Saltpetre Kop and Blaauw Blommetjes Keep agglomerates; to the remarkably well exposed neck at Ratel Fontein (Balmoral) in Fraserburg;* and to the Kimberley pipes. In the case of the melilite-basalt neck of Spiegel River evidence of this nature could not be expected, as that locality is far from any known intrusion of the Karroo dolerite. The dolerite fragments in the agglomerate, and the cutting through of the intrusions by the pipe rocks, proves that the latter were produced after the dolerite had solidified. There is reason to believe that the Karroo dolerites belong to the Stormberg period, but the full discussion of the reasons for this would be out of place in this Report. The pipes must be looked upon as of post-Karroo age. In the second place, the presence of such an unusual type of rock as melilite-basalt in necks at Sutherland, Matjes Fontein, and Spiegel River, in spite of the differences between the rocks as described above, gives a strong family likeness to the three occurrences, and fits in remarkably well with Carvill Lewis' supposition that the blue-ground of Kimberley was derived from a melilite-basalt by alteration. In the third place, the contents of all the vents we have dealt with are very different from those of normal volcanic pipes. In the place of ordinary lavas, and tuffs and agglomerates derived therefrom, we have secondarily silicified and ferruginous rocks, with a large amount of débris from sedimentary strata, and from what are usually considered deep-seated rocks, granites and eclogites, in some cases lying in a matrix of altered olivine, perofskite, calcite, and ilmenite.

In the Memoir on the Geology of Eastern Fife† Sir A. Geikie mentions the occurrence of large fragments of hornblende crystals, orthoclase, and pyrope, in some of the agglomerates of Eastern Fife, and he remarks upon the general resemblance of those rocks to the Kimberley agglomerate; but he also says of the minerals, "like these (*i.e.*, minerals included in the Kimberley rock), they have been thrown up by volcanic explosions from some deeper part of the crust, but without revealing very closely the nature of the magma in which they were originally generated."

The pipes in the Sutherland Division must be regarded as holes blown through a great, but unknown thickness of rocks, and filled with various materials, some derived from the rocks pierced by the explosions, others from a liquid magma (of which the melilite-basalts are one of the products), that was probably closely connected in origin with the volcanic explosions, and others again (the eclogites, etc.) from an unknown source; possibly the latter materials were a portion of the same basic magma which also yielded the melilite-basalt, but in the absence of the results of chemical investigations there seems little in common between the hornblende-augite-biotite-garnet-ilmenite-plagioclase rocks and the olivine-melilite-augite-perofskite-biotite-ilmenite rocks.

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* See Geol. Commission for 1900 (p. 60).

† By Sir A. Geikie; Memoirs of the Geological Survey of Scotland, 1902 (p. 271-2).

The most unusual extent of the qua-qua-versal dips round the central Saltpetre Kop vent is worthy of special attention. Before this hole was formed, or during its formation, the strata were arched up in a dome-form about the chief centre of explosion in the area; the smaller vents, whether independent of the larger one throughout their extent or not, have no appreciable effect on the dip of the rocks traversed. A qua-qua-versal dip seems to be a very unusual feature round volcanic necks, if we exclude the slight upturning of the edge of the surrounding beds at the immediate contact with the neck, as is the case at Kimberley and in the Balmoral (Ratel Fontein) pipe. Over a wide area the reverse dip is more usual near volcanic centres, that is a sinking of the surrounding strata, as if to partly fill the cavity caused by the loss of the material thrown up by the volcano.

The secondary deposit of silica, hydrated oxides of iron, and calcite, as well as of barytes in a few cases, probably took place at the close of the period of activity, and is analogous to the results of the "solfataric" action in recent volcanic regions.

SUPERFICIAL DEPOSITS.

The greatest continuous area of recent deposits is that of the raised river terraces of the Tanqua Valley, at an approximate height of 1,600 feet above sea level. The principal terrace commences on the farm called Tanqua River (Sutherland Division), and extends down the river as far as the farm Onderstewagendrift (Ceres Division), a distance of about 23 miles; it covers a total area of almost 100 square miles.

The gravels forming this terrace are almost entirely confined to the right bank of the river and its north-eastern tributaries, but a considerable extent of gravel is also found in the valley of the Hout Hoek River, which runs northward from the Koedoes Mountains and joins the Tanqua River at Blaauw Heuvel.

Over the greater portion of its area the terrace has been cut in the soft black basement shales of the Ecca Series, and where they occur the surface is remarkably smooth and level, unbroken by any mounds or ridges; but at Blaauw Heuvel, and from thence farther up the river, the terrace has been cut in harder beds, and small ridges of hard sandstone occasionally project through the gravels.

The altitude of the terrace above the bed of the present river is very constant, from 90 to 100 feet, and the branches of the Tanqua have cut down through the gravels and underlying beds leaving a number of flat-topped areas standing; the main road along the Tanqua Valley has been carried up and down these in a most primitive fashion, making waggon-travelling very difficult. The gravels are usually from three to four feet in thickness, and consist of fragments of Ecca and Beaufort sandstones, though pebbles of shale and vein-quartz also occur. The boulders are well rounded by fluviatile agencies, but owing to their subsequent exposure to the action of the weather they are often deeply pitted and eaten into, so that sometimes a thin shell of sandstone alone remains. The gravels have not been cemented or in any way compacted, so that they form a loose mass resting on the Ecca platform. The gravels have not been found farther down the Tanqua than the Rhenoster River, which may be due to the removal of the terraces by the lateral erosion of the river.

In addition to the main terrace just described there are patches of similar gravels at a lower level also, about 20 to 25 feet above the present river bed, but of limited extent only. A small plateau of gravel occurs on the left bank of the Groot River (Dwequa), just north of Tover Kop, the boulders being to some extent cemented together by calcareous material. The Ecca shales forming the plains of the Groot and Doorn Rivers are strewn with rounded sandstone boulders over considerable areas, but nowhere is there seen the regularity which characterises the Tanqua River gravels. Large tracts, also, are covered with calcareous and siliceous breccias and conglomerates; for example, on the farms Karree Kolk and Groot Fontein. Just outside Karroo Poort there is a wide stretch of sandy gravel brought down by the rivers and streams, draining the country north of the Warm Bokkeveld. The pebbles are chiefly of Witteberg and Bokkeveld sandstones and quartzites. The main stream beds lie some 30-40 feet below the surface of the gravels.

Northwards from Karroo Poort there is a discontinuous terrace on the slopes of the Zwart Ruggens at a height of some 100 feet above the Doorn River. The boulders are almost entirely of Witteberg quartzites, and the matrix is sandy, often with a ferruginous cement. This gravel conceals the junction of the Witteberg and Dwyka Series for many miles south of the confluence of the Tanqua and Doorn Rivers. The boulders are subangular, and rounded, the larger ones are about 2 feet in length. The ferruginous cement seems to be derived from spring water, for there are ferruginous springs rising along the boundary of the Dwyka and Witteberg Beds in this neighbourhood. At Kopper Fontein the water from a spring deposits a yellow rusty substance in its channel and on any object that happens to be hanging in it, very much in the same way that the Caledon hot spring water does, but the Kopper Fontein water is at the ordinary temperature so far as one can judge by putting one's hand in it.

Calcareous matter also cements together the materials in the gravels; it probably comes from the Dwyka Conglomerate in the neighbourhood, as the spring and soakage water from the Conglomerate usually contains carbonate of lime.

These gravels were deposited by the streams draining the Zwart Ruggens at a time when the level of the Karroo at the foot of the slope was 100 feet higher than at present.

In the Bosch Kloof Valley, and the alluvial plane stretching from the hills east of the main road to Calvinia to the Witteberg hills west of the Poortje there is a great accumulation of silt. The Poortje pan is a silted up depression caused by the diversion of the north branch of the Bosch River southwards into the south branch at a higher point in the course of the latter than was formerly the case.* An examination of the curious gap in front of the pan, through which the river used to run, shows that the old valley is filled up with bedded sand and silt to a very considerable depth, which could only be ascertained by sinking a hole through the alluvium. A well put down on Witte Kloof (Witte Vlakte West) passed through 240 feet of alluvium without striking the solid rock. The height of the surface at this spot above that of the nearest rock exposure in the Doorn River is not known, so it is at present difficult to decide whether this great amount of alluvium is due to an upward movement of the river valley below Witte Vlakte, or whether it may be accounted for by some other explanation, such as the blocking up of the Poortje channel by local debris and the consequent turning of the river bed southwards at a time of flood, or the prolonged resistance offered by a bar of rock lower down the river, owing to which the river levelled the country above the obstruction and deposited silt upon the plain and channel so formed, but the 240 feet of silt seems too great a thickness to be accounted for on this hypothesis.

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* See Ann. Rep. Geol Com. for 1900, p. 40.

This wide area of thick silt would be most valuable for agriculture were there a convenient source of water. At present it is sparsely covered with bush, and every heavy storm cuts deep ravines through the alluvium. The sand and dust blown from one spot to another partially obliterates these ravines before the next rain falls; so that each storm has to make new watercourses .

Valuable tracts of alluvium are found along the Great Fish River in the Roggeveld in the Sutherland Division, but these are much less extensive than the rich lands further down the river in Calvinia, outside the area of the present survey.

WMORE

GEOLOGICAL SURVEY

OF PARTS OF

PRINCE ALBERT, WILLOWMORE & UNIONDALE,

BY E. H. L. SCHWARZ.

The present report deals with a section of the folded coast belt between the village of Prince Albert and the end of Baviaan's Kloof in Willowmore. As a whole the country traversed was fairly closely mapped, but there are some gaps caused by local circumstances which prevented me from getting to such areas. The most serious of these was the drought, which was very severely felt in the district, as the farms had not yet recovered from the effects of the war; very little forage was to be had away from the villages, and transport was difficult to get. Another hindrance which proved very annoying when detailed work was necessary, as in Baviaan's Kloof, was the badness of the maps. The maps of the Divisions of Prince Albert and Uniondale are on the scale of two miles to the inch, and when one gets used to the country are sufficiently accurate to lay down the geology on; but the map of the Division of Willowmore is on the scale of three miles to the inch and contains many blanks of unsurveyed areas.

The country is intensely folded throughout, and would have repaid a very minute and lengthened survey, but there are so many points which have to be settled first, before the finer work can be commenced, that the mapping done was on broad lines only. No attempt was made to locate with any accuracy the particular beds in the different formations or the actual angles and courses of the multitude of small bends, but a full account of the general nature of the rocks, the conditions under which they occur, and the part they play in the present surface features of the ground, will be found in the ensuing pages.

For the convenience of description I have divided the country into areas which form in themselves certain provinces in which the same features, both geological and geographical, are equally present. They are:—

(1) From Prince Albert village to Willowmore.
(2) Tygerberg and the Gold-Fields.
(3) Zoetendal's Vley and Swanepoel's Poort.
(4) Willowmore village.
(5) The upper Olifant's River.
(6) The Kammanassie River and the western end of Long Kloof.
(7) Baviaan's Kloof.

I.—PRINCE ALBERT TO WILLOWMORE.

The main road runs between the two villages on Bokkeveld Beds and on the south side there are the Zwartebergen, made of Table Mountain Sandstone, and on the north a range of hills made of Witteberg quartzites. The arrangement of the beds is very similar to that on the east side of the Cederbergen,* and in both localities the older sandstone formation towers into lofty peaks, while the younger sandstone formation, although intensely folded, is cut into a more or less level plateau. In the Cederbergen the strike is north and south, in the area under discussion it is east and west. The general plan of the whole is simple, the Table Mountain Sandstone is in the form of an S-shaped bend (Fig. 2), the syncline on the seaward side and the anticline on the inland side; the Bokkeveld Beds crop out as a band overlying the Table Mountain Sandstone and the Witteberg Series overlies the Bokkeveld Beds, and has the area of its outcrop extended laterally by a number of upright folds. When one is placed, however, in the field, amid the extraordinary multiplicity of minor folds, one is apt to lose sight of these main structural lines. The region has often been traversed, owing to the proximity of the Prince Albert Gold-Fields, to the great mountain road that connects Oudtshoorn with the railway, and to the fine springs that come from the mountain and the gorges that have suggested the building of great dams. People have again and again explained the structure of the mountains and adjacent country, but so far without any clear insight into their true nature. From an inspection of the sections in the subjoined list, it will be seen how much the small folding has obscured the larger features.†

The Zwartberg range is typically, as already mentioned, a double fold with minor wrinklings, but there are many subsidiary folds as well. These last do not lie exactly parallel to the axis of the main range, so that a section of a mountain side in any kloof will not be repeated in the rest. Indeed, the width of rock removed from the actual kloof is sufficient to give a different pattern to the folding in either wall.

In Gamka River's Kloof, to the west of our area, there is little complication,‡ the section from the north southwards, is a northerly dip; then a long flat portion; a southerly dip bringing in the Bokkeveld Beds; and then another anticline. The last is denuded away over the greater portion of the southern slopes of the mountains; a small area remains far to the east which will be described later (p. 105), but between these two points there is nothing but the underlying Cango Series, constituting the base-rocks of the Cango.

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* See Ann. Report for 1900 (p. 65 and onwards).

† W. Molyneux, Report on the Survey of the Karroo and Stormberg, Cape Town, 1881, Section to face page 12. A. H. Green, Report on the Coals of Cape Colony, Cape Town, 1883, Plate I. A. R. Sawyer, Report on the Geology and Mineral Resources of Prince Albert, Cape Town, 1893, Section 4. W. Wilcocks, Report on Irrigation in South Africa, Johannesberg, 1901, Sketch 2.

‡ Ann. Report, Geol. Comm., 1899, Cape Town, 1900 (p. 34).

In the Zwartberg Pass, going over from the north on the Prince Albert side, we find the Table Mountain Sandstone dipping south at a high angle and the Bokkeveld Beds apparently passing beneath it. Here then we get the first indication of an excess of southerly dip, which increases as one goes southwards and eastwards, and assumes such perplexing preponderance in Uniondale, George, and Knysna. Assuming the thrust that crumpled these mountain ranges to have come from the interior, the reason for this southerly dip in both limbs of the syncline and anticline is that the upper portion of the folds toppled over, as it were, northwards. After passing through the first narrow gorge, the traveller enters an open space formed by east and west valleys; here, on either side there is a zone of the most wonderful folds, a regular succession of equal synclines and anticlines arranged—not on a horizontal plane as is usually the case, but on a plane more or less vertical. South of this zone again, the rocks stand vertical, and even dip at slight angles to the vertical northwards. The same succession was found in the Gamka Poort on the same line as this, but the structure was simpler there as the zone of small folds was in the hinge of the bend, that is, where the rocks which are horizontal in the mountain dip northwards on the northern edge. I think the same explanation holds good here: the presence of a great amount of folding in which the crushing was perpendicular to the earth's surface, can be explained only in the supposition that the sandstones in the act of bending compressed and forced downwards the inner strata (see Figs. 2 and 3). This may perhaps be best illustrated by thinking out what happens on a small scale and then applying it to the rocks in the field. Take a piece of any pliable material and bend it at right angles, the outer angle of the bend will be in strain and in many instances will crack, while the inner will be correspondingly under stress and will pucker up. Such action has taken place on a large scale in these mountains on the northern side, and whereas the outer surface has been prevented from cracking by the clinging of the shales above to it, the inner surface of the bend has had to take on itself all the accommodation necessary: the weight of material coming down on the beds, has produced the vertical crush.

The road now climbs westwards along the sides of a lateral stream, passes over it, and then by a series of zig-zags attains the first part of the ascent. Between the first height and the summit there is a wide stretch of flat ground. This is in the line of the main syncline though the nature of the bend cannot be seen from this particular locality: all the beds apparently dip at a high angle south, but on travelling westwards the valley becomes more and more pronounced until it gives place to a tract of Bokkeveld Beds enclosed in the heart of the mountains.* On the east the same thing happens, but here the strip of Bokkeveld Beds widens out, and the Table Mountain Sandstone on the north, instead of enclosing it, sinks underground and forms a point directed eastwards (Fig. 4). The mountains are exceedingly difficult to get about in, as the kloofs are so precipitous, rendering it practically impossible to travel along the mountains across them: the structure, therefore, has to be made from transverse sections obtained at various points in the chain.

After passing over the wide, open plains, the road begins to climb the final ascent to the top of the pass, finishing by another series of zig-zag curves. Near the top the rocks are more hardened by secondary infiltration of silica than lower down and are therefore more compact. Worm-tubes and ripple-marks may be observed on the face of some beds on the north side of the summit. The height of the pass is about 3,000 feet above the village, the latter being 2,120 feet above the sea-level.

From the summit of the pass the beds dip south at a very high angle. The rocks on this side contain a good deal of shale between the massive banks of sandstone, but owing to the intense pressure that it has undergone, it has been converted into a micaceous, talcose material usually weathering red, but occasionally bleached white.

Eastwards of the pass the zone of wrinkled strata comes nearer the northern margin of the outcrop, and we get the actual dip-slope that carries the Table Mountain Sandstone beneath the Bokkeveld Beds, most intensely folded. There are two stages in this kind of crumpling. The first is that in which the beds are bent into a number of right-angled folds, "knee-bends," as we may term them; a condition of things that we shall see later on is represented in the northern side of the Kammanassie Mountains: in this stage there is little distortion, but in the next, where the pressure has been greater, the knee bends are crushed together, and drawn out into long sigmoid curves; the more massive beds have lagged behind the weaker beds and differential movement in the mass of the rock has taken place (Fig. 1).

No better places for studying this latter stage exist in the Colony than in the Zwartebergen between the Zwarteberg Pass and Meiring's Poort. At both these places and in the kloofs running into the mountains on the northern side, for

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* Ann Report Geol. Comm., 1899, Cape Town, 1900 (p. 34).

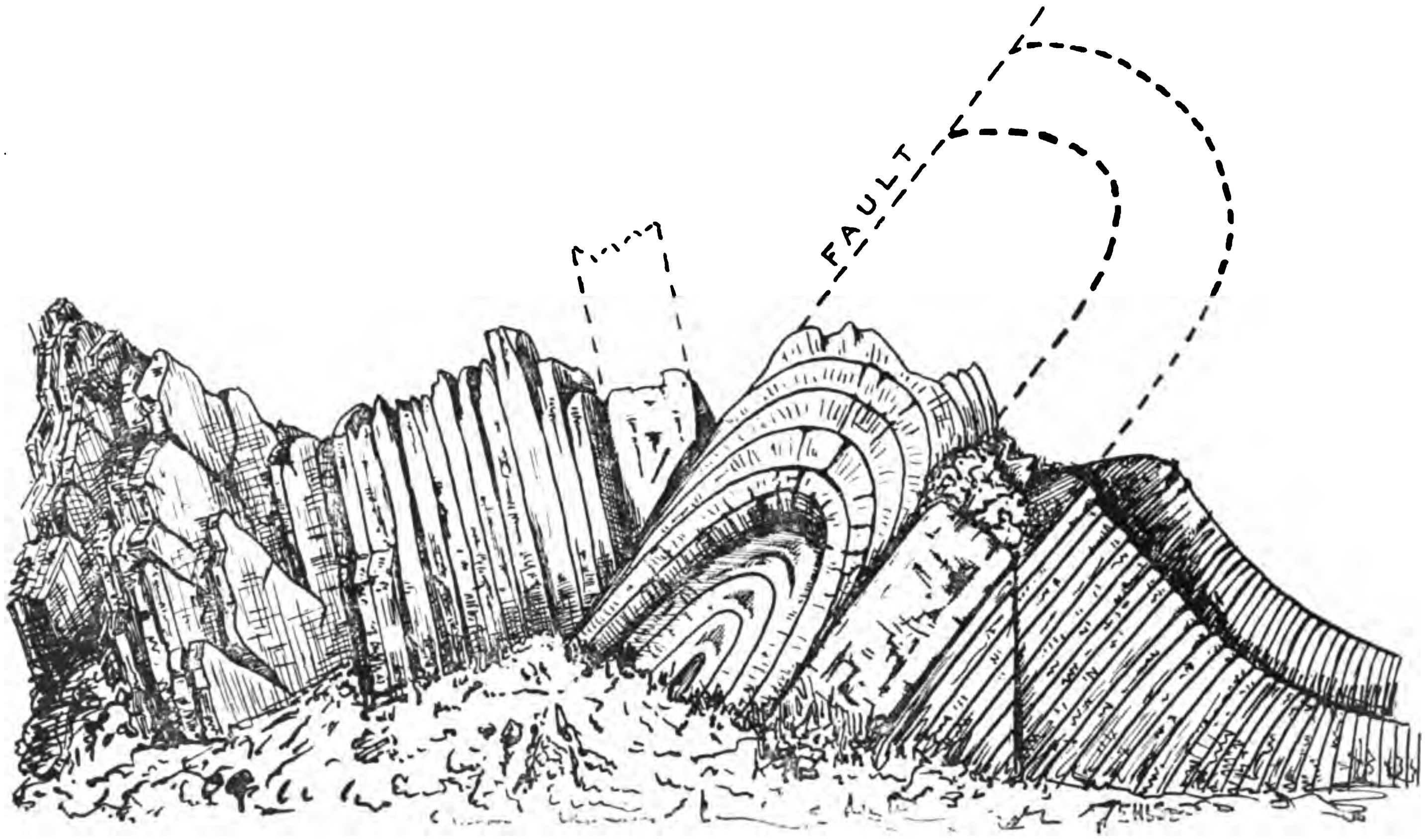

FIG. 1.—The northern edge of the Table Mountain Sandstone in the Zwartebergen, on the west side of Angeliers Kloof, Prince Albert. The sketch shows the compression of weak sandstone beds between the "jaws" of a massive bed; the latter is about four feet thick,

instance, at Angelier's Bosch, Roosendal, and Vrisch Gewaagd, the most wonderful examples can be found.

The effect of these folds on the stratigraphy is very complicated, and it is impossible to adequately represent the structure of the country here on a map. The Table Mountain Sandstone at the edge of the mountains is folded with the Bokkeveld slates above it, and odd lengths of the summits of the folds appear through the overlying formation. At Roosendal, again, the bottom of the kloof for a good distance in the mountains is in Bokkeveld Beds, but the top of the kloof walls is in Table Mountain Sandstone which has been thrust horizontally over them. It is when looking at these folds that one can first realise how, for instance, in Knysna,* Bokkeveld Beds can be completely enwrapped in the Table Mountain Sandstone, a feature which we shall see repeated in Baviaan's Kloof (Fig. 10, p. 128).

In the Zwartberg Pass we have an unparalleled view of the outside of the mountains†; in Meiring's Poort, thirty-five miles to the east, we can study their internal structure. The poort cuts through the Zwartebergen, where they are some 6,000 feet high, the great peak, Blaauw Punt, to the east, is 6,988 feet,‡ the river bed being 2,000 feet, (Fig. 4). Judging from the trend of the rivers generally, as they come from the main watershed of the Colony, it seems possible that originally the Gamka or Lion River passed through Meiring's Poort, but subsequently the Dwyka River captured the Gamka River's waters; then what little was left to the Meiring's Poort River was again captured by the Traka or Maiden River, so that at the present day an exceedingly small area drains through the poort. This diversion of the rivers may have taken place by ordinary methods of river erosion, but as the rocks traversed by the Meiring's Poort River differ in no way from those traversed by the Dwyka and Traka Rivers, it seems difficult to understand how it is that the Meiring's Poort River was not able to hold its own in the struggle for drainage areas. I think it more probable that there has been a rise of the land in the form of a broad qua-quaversal anticline, the eurycolpic fold of Moore, and which was connected with the system of broad folds that has separated the Uitenhage deposits in the Olifant's River and Baviaan's Kloof basins into a number of isolated patches. Whatever may have been actually the cause of the diversion, the diversion nevertheless is a very real thing, and the difficulty that people have of explaining how so small a river could have cut so large a poort is thereby got over. There is no question of rending or fracturing of the mountain; the river course has the windings of an ordinary stream, and is altogether different from one formed, like the lower course of the St. John's River, for instance, by dislocation of the strata. I was, however, unable to gather any further information to settle the question as to whether the river was running before the mountains were formed, and the latter were being slowly folded, rising across the bed, but at such a slow rate that the river was always able to cut its way down without being diverted,* or, whether when the river first assumed its course,† the mountains were already formed but buried to their tops in deposits of Uitenhage and later systems; the river then flowing over the whole cut downwards, removing the loose gravel and sands, but leaving the solid Table Mountain Sandstone.

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* Ann. Report Geol. Commission for 1899, Cape Town, 1900 (p. 57).

† Dr. Molengraaff says "Their wild beauty here is not inferior to the best Alpine scenery," Neues Jahrbuch, Bd. 1, Heft 2, 1900 (p. 115).

‡ Sir D. Gill, Geodetic Survey of S. Africa, Vol. II., Cape Town, 1901 (p. 169)

At the north end of Meiring's Poort, there is a considerable width of folded Bokkeveld Beds, and the road laid beside the river passes between high hills of that formation. Before the actual mountain is reached there is a tract of more open country where the side streamlets come into the main river, and the toll-house is placed here. The Bokkeveld Beds dip under the Table Mountain Sandstones at an angle of 45° or more (Fig. 2). On the east of the portal or entrance to the kloof, the manner in which this over-fold is accomplished is well seen. The sandstone beds on top of the mountain are lying flat, and the whole series of sandstones can be seen completely turned over and

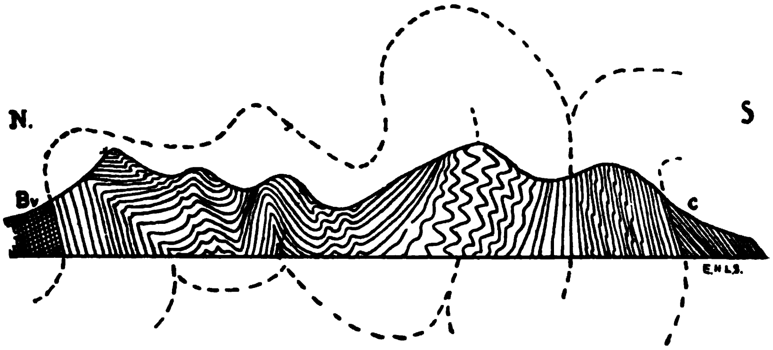

FIG. 2.—Generalized section through the Zwartebergen, taken through Meiring's Poort. Bv. Bokkeveld Beds. C. Cango Beds. The folded rock is Table Mountain Sandstone, 5,000 ft. thick. The syncline and anticline which are closely pressed together on the south side constitute the main folds of the range, and are what have been termed in former Reports the S-shaped folds; it is this form of fold which dominates in all the western coastal ranges of the Colony,—1st Ann. Rept., 1897, p. 27. The incomplete anticline on the south side is joined up to the east with a southern limb, but in this portion of the range the latter is faulted beneath Uitenhage deposits in the Oudtshoorn Division.

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* E. H. L. Schwarz, The Volcanoes of Griqualand East, Trans. S. A. Phil. Soc. Vol. XIV. (p. 108).

† A. W. Rogers, ib. (p. 378).

bent under, the Bokkeveld slates faithfully following the inversion. This fold is not a small minor fold, but one affecting the whole thickness of the Table Mountain Sandstone; it forms a roll or additional anticline on the north of the mountains. Above where the rocks lie flat, there is a level tract of grass-covered veld, forming a shelf to the mountains behind, which ends near Hagas or Uitnod by the over-thrust anticline passing beneath the present surface. On the west side of the entrance the hill-side is nearly vertical, and a tremendous section is afforded of the flat beds on top bending round and dipping beneath themselves. On the outer side of the bend, the beds of sandstone simply make an acute angle with themselves, but further in, the material caught in the bend has been forced back, causing the beds to assume an M-shaped outline.

Further in the poort one comes to the first line of peaks which form the top of the mountain chain when seen from the north. This line is practically level with the southern chain of peaks or the Zwartberg Pass, and on both of them are the beacons forming the boundary of the Prince Albert and Oudtshoorn Divisions; owing to a southerly bend of the whole range the real continuance of the latter is to be found further to the south at Meiring's Poort. At the Zwartberg Pass, also, the chain of peaks that face the north disappears near Klaarstroom, and the first peaks on the Meiring's Poort section belong, therefore, to an inner set, which is not recognisable on the Zwartberg Pass: this section in turn disappears underground by the main road from Willowmore to Uniondale. At Meiring's Poort the eastern peak is best exposed: there is a vertical wall of rock some 3,000 feet high, on which the beds are lying almost flat. Towards the top, however, some well developed knee-bends appear and a tract of crumpled rock is exposed on the mountain side, the crumplings lying lower and lower till in the neighbourhood of the waterfall they reach the stream-level. Before reaching the waterfall the folding, instead of having the limbs vertical and horizontal, or to put it another way, with the plane of folding inclined at 45° to the horizontal, becomes upright, that is, the limbs are equally inclined to a horizontal plane.

The waterfall lies in the debouchment of one of the lateral streams into the main stream. All these side streams have such an entrance, but the particular one meant when the "waterfall" is spoken of, is a permanent stream coming down from a considerable gathering ground above. The water falls over a ledge into a barrel-shaped hollow, and the entrance to this is, as it were, through a slit in the barrel. The pool below is very deep, and continues the same shape below the surface of the outlet; the width in the "barrel" is about 20 yards, and the height of the waterfall 60 feet. It appears impossible at first sight that so small a stream should have drilled out by itself so wide and regular a chimney in the hard quartzites, but all stages in the growth of such hollows can be seen in the mountains of the district, and there is little doubt that the attrition of stones whirling round and round has been the sole cause of the chimney: a larger example of the same thing occurs at Kaaiman's Gat in the George Division.

Beyond the waterfall the kloof becomes less interesting, and the mountains on either side considerably lower. The dip of the rock varies, but is always southerly; there are small areas of wrinkled strata, but compared with that which soon follows this folding is insignificant.

Still going southwards, winding alongside the stream and crossing from side to side innumerable times, one comes at last to a northerly dip; the beds where this begins being very massive and folded in great knotty bends, very different from the clearly defined ones on either side. The mountain face that follows is a true dip-slope, with the beds thrown into comparatively very small bends, imparting a wavy form to the whole.

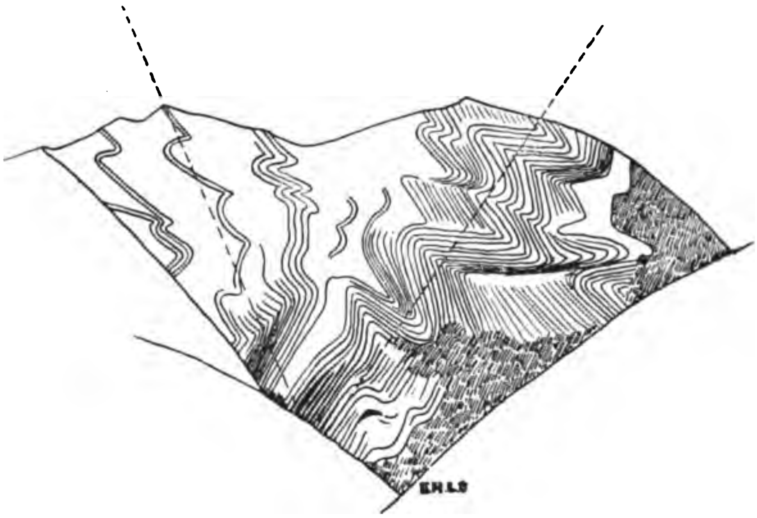

FIG. 3.—Meiring's Poort, Oudtshoorn end, eastern side. Diagram of folds to show the divergence of the planes of crumpling.

The extent of the northerly dip is small even on top of the ridge; the rocks bend again south and continue with a steep southerly dip to the end of the poort, but where the actual bend occurs, there is a tremendous exposure of intensely folded rock, the general plane of the folding being vertical, with a thrust to the north on the higher parts of the mountain (Fig. 2). Drawing a line through each successive series of folds, so as to take, as it were, an average of the curves, these lines will be found to diverge upwards, fan-wise (Fig. 3). There are many beautiful examples of the folds passing into thrust-faults, the plane of the thrust being inclined at only a small angle to the horizon. This portion is certainly the finest example of contorted beds that is known in the Colony, where folding is especially well developed; it is shewn on such a large scale here on the face of a cliff about 2,500 feet high, very little encumbered with debris, and in a hard rock like the Table Mountain quartzite. It is, however, impossible to describe the place without ample diagrams and illustrations; I can only here refer to it as an extraordinary one, and, as far as tectonic geology is concerned, most instructive. The angles of the slope of the gorge are very steep, those on the inside of the bends of the streams being 45° and on the outer side 70°, sufficient to make the cliff appear actually vertical.

Beyond the crushed area, the beds dip south at a very high angle, and there are numbers of small kinks by which the almost vertical beds are pushed southwards in respect of the lower portion. Some of the "kinks" well repay study, as one can notice how in successive strata the amount of curvature increases till a thrust-fault is produced.

It is very difficult to make out the major folding in this portion, as the bends are pressed together and both limbs dip equally to the south, but from the structure of the mountain-range generally, I believe that there is an anticline represented in the crushed area, and between this and the end of the poort a syncline, being the end of the syncline that we saw in the Zwartberg Pass, where it already was scarcely recognisable; in Meiring's Poort it has become so folded together that one cannot notice any particular place which one could say was the centre of the bend.

The southern end of Meiring's Poort opens on Cango Beds, lying folded very nearly, in many places perfectly, parallel to the Table Mountain Sandstone. On the western side of the entrance, however, the unconformity is rather more marked than usual.

All these folds that have just been described die out before reaching the end of the range, and it is the anticline which should normally arch over the Cango Beds to the south of Meiring's Poort that eventually carries the range on to its termination: how this anticline is formed will be described later (p. 105).

We get, therefore, as a final idea of the whole Zwartberg range, commencing at Anysberg and ending at Slypsteenberg, a folded tract of Table Mountain Sandstone rising from low ground occupied by the Bokkeveld Beds, and trending east and west, in which the folds are set on at a slight angle to the axis of the mass, so that every now and again along the northern edge these folds disappear underground, sometimes making points that project from the mountains in among the Bokkeveld kopjes. The whole length in a straight line is 170 miles.

Before the range comes to an end there is still one more poort, called "Toverwater," through which the Traka or Maiden River runs. The railway is now carried through this, but beyond a fine section of vertical rocks, there is little new to see in the Poort after going through the Buffel's River, Gamka River and Meiring's River Poorts.

The Bokkeveld Beds occur in a narrow strip north of the Table Mountain Sandstone, and are intensely folded. The usual zones, or, at any rate, the regular succession of sandstone and shale that one is accustomed to in the west, is different along this tract, and I believe that it is not only the shearing that has disguised these differences, but that there is here an actual difference in sedimentation as well, as we had reason to believe was the case in the Caledon and Swellendam Ruggens. There is undoubtedly only one main bed of sandstone which corresponds to the Second or First White Sandstone in the western series; others appear feebly in the sides of the kopjes, but are too irregular to classify. Fossils occur sparingly and only near the base, where a few *Leptocoelias* and *Terebratulas* are found.

In going from Prince Albert to Klaarstroom, after leaving the road to the Pass, the road is carried for some distance over micaceous shales and sandstones, which are, I believe, the same as those in which we found *Spirophyton* further west along the Gamka River; the exposures are not good here, and it was at Roosendal, some three hours from the village, that I first found the *Spirophyton* in these beds; the locality was south of the homestead. The same difficulty of dividing the Bokkeveld from the Witteberg Series has so often cropped up, and will also be referred to again in this report, that I will merely state here that I have assigned over this portion only a narrow band of slates to the Bokkeveld; a further band of slates, different in composition, in that they are more micaceous and gritty, which underlie the true Witteberg quartzite, I have assigned to the younger formation.

Narrow as the band is, there are numerous folds traversing it. At Angelier's Bosch the folds are seen coming through the Witteberg quartzite and affecting the Bokkeveld Beds, but stopping apparently at the border of the Table Mountain Sandstone. The folds here strike E. 15 S., and are sharp anticlines and synclines, some four or five in number. In some of them there is overthrusting, and the synclines take the shape of a V, with one limb lying horizontal. The ground is too broken to follow the folds closely.

Beyond Kredo Berg, which is a nek dividing the tributaries of the Gamka and Meiring's Poort Rivers, the character of the valley remains the same for some distance, and then widens out owing to the decrease in height of the Table Mountain Sandstone outcrop; there are here wide gravel-covered plains. The sandstone as previously described makes a point here, and between it and the continuation of the mountains there is a tongue-shaped enclosure of Bokkeveld Beds, forming the lower ground of the farms De Aap and Klein Vley. Looking up this valley one sees a crowded aggregate of the usual clay-slate kopjes covered with rhenoster bush, between which the main stream

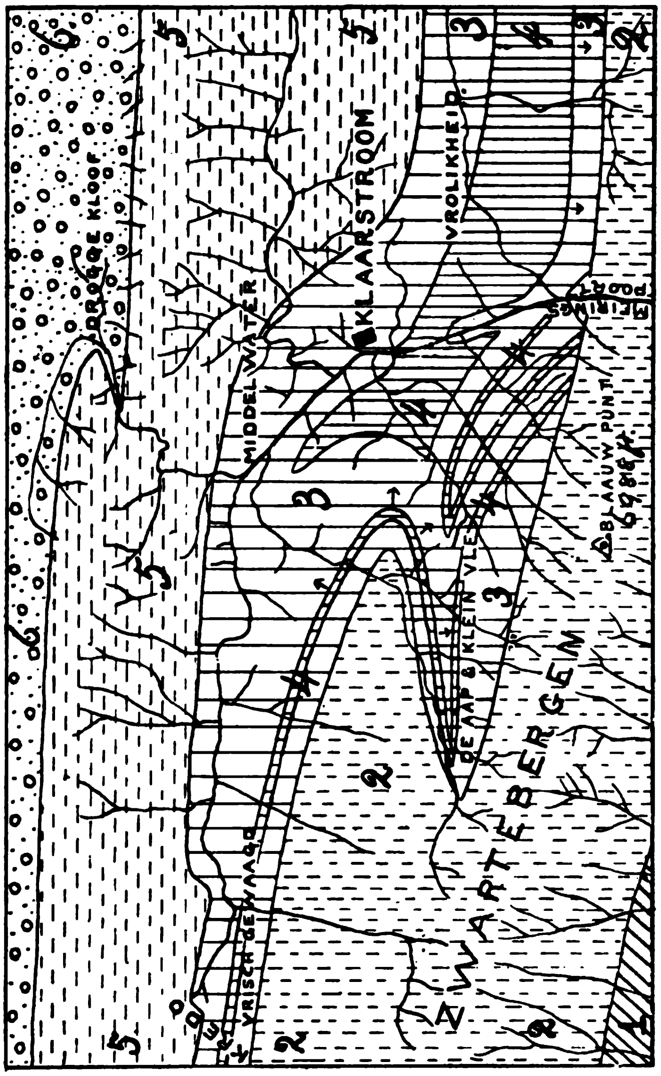

FIG. 4.—Map Showing the Distribution of the Beds round Klaarstroom. 1, Cango Beds. 2, Table Mountain Sandstone. 3, Bokkeveld Beds, with the Second Sandstone, 4. 5, Witteberg Beds. 6, Dwyka Series.

and the lateral ones are sunk in deep channels. All the beds are dipping south at a moderate angle, 30°, and sometimes a little more. On the south, the Table Mountain Sandstone shows a scarped front, with the slates dipping under the lower portion in the hill-side. On the north, the Table Mountain Sandstone shows regular dip-slopes, to which the slates still cling. The variation in the nature of the beds is well brought out here by weathering, and a harder rock, corresponding to the Fossiliferous or First Sandstone forms a shelf below the more massive Second Sandstone above. These shelves are regularly scolloped. Towards the centre of the valley the dip is less, and another line of sandstone-capped hills occurs, with the same rounded contours; it is impossible to state whether this is the Second Sandstone reduplicated by bending, or whether it is a Third Sandstone. Between the last and the Table Mountain Sandstone, there is a zone of clay-slates showing no hard bands.

Round the point of the mountain, the Bokkeveld sandstone shows a scarped face underlain by shales, making an amphitheatre, with the sandstone showing like a wall on top of the steep slope. Between this and Klaarstroom, and eastwards, the Bokkeveld sandstone occupies a very large surface of the ground, being thrown into broad synclines and anticlines. The side streams that run into Meiring's Poort River cut through it and expose vertical walls made of sandstone, that at first lead one to suppose that one is dealing with Table Mountain Sandstone. The thickness of this bed corresponds with that actually measured in the Gamka Poort, which gave 419 feet*; it is impossible to compare weathered sections with this ideal section, which is kept fresh by the action of the water, but there occur at our present locality similar dark sandstones, and also beds made largely of lime; these latter weather in pillowy forms, not unlike those which the Dwyka Conglomerate often assumes. The outcrop of the Second Sandstone is arranged here in the form of an N, Fig. 4; by Welgemond (Blaauwpunt) the line of hills made of it come diagonally from the Table Mountain Sandstone border at about W. 15 N. Near Klein Vley they turn sharply back towards Klaarstroom in a direction E. 15 N., then turning back to the west again, to follow the Table Mountain Sandstone border. Where the rock is folded into an anticline, one notices, especially along the Meiring's Poort road, that the Second Sandstone has formed, as it were, a confining band to the shales beneath, and the latter, besides showing the bedding-planes parallel to the surface of the sandstone, also show shear-planes arranged radially to the curvature; had the sandstone responded to the crushing equally with the shales, the shear-planes would have been parallel to each other.

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* Ann. Report, 1899, Cape Town, 1900 (p. 48).

At Vrolykheid there is a stream coming almost straight from the mountains, exposing a section of this sandstone, which can be more easily followed than in the more complex region around Klaarstroom. Beginning at the homestead, there are two hills capped with sandstone, with the strata in each dipping north; the northernmost seems to be a capping of the Third Sandstone. The other is part of an anticline of the Second Sandstone; between it and the other limb of the fold there is a wide area of shales. The southward dipping portion shows a black sandstone near the base that is characteristic of the Second Sandstone; beyond this there are three well-marked broad anticlines pulling out the outcrops of the Second Sandstone to about a mile in breadth. The last anticline ends abruptly in an escarpment, formed by the breaking away of the crest, and between this and the Table Mountain Sandstone there is a wide strip of featureless clay-slate, such as we saw at De Aap and Klein Vley. The Table Mountain Sandstone lies flat at the foot of the mountain here, but there is enough above the surface to show that it is folded under, the bent portion showing a large number of small knee-bends. There is a good deal of shale in the topmost beds of the Table Mountain Series here.

Beyond the Traka River, the Bokkeveld Beds widen out and assume a more important role in the topography of the country; this part will be found under the section devoted to the description of the Willowmore village area.

The Witteberg Beds, though no thicker than the Bokkeveld Beds, occupy a much broader area in the district under description owing to the number of folds in them. At the Prince Albert end these have a north-westerly strike, and the rivers are deflected accordingly; further east, the strike becomes east and west.

A good idea of the area can be obtained on the road from Roosendal to Kaffir's Kraal, through Brand en Spochter's Gang. At the edge of the outcrop of the quartzites there are some small folds, but presently the whole of the rocks dip uniformly south, till the crest of the nek is reached; at this level the beds become flat with two small monoclines, having the downthrow to the north and the hade also to the north. Before this part has been reached, however, the whole thickness of the quartzites has been reduplicated by a syncline, but owing to the two limbs being crushed together, there is no direct evidence of its occurrence.

North of the nek there is a wide flat drainage-area in the hills, caused by the river flowing over the intensely hard quartzite which occurs on the northern outcrop. This dams back the water, and tends to make all the small rivers with small erosive power spend their efforts in degrading the rocks behind to a dead flat. There is a sharp anticline here, and both limbs dip south, the northern one at a higher angle than the southern;

this causes the Dwyka Conglomerate and the accompanying shales to dip beneath the quartzites, just as the Bokkeveld Beds dip beneath the Table Mountain Sandstone.

The Kaffir's Kraal Dwyka rocks occur in a very narrow band tucked in under the quartzites; they are badly exposed owing to surface sand and rubble. On the north side the Witteberg quartzites rise up with great bare dip-slopes, with rounded surfaces inclined from 45° to 60° to the horizontal. There are shales above the terminal hard quartzites here, and between the Conglomerate and the shales there is a thin band of quartzite which is not often visible; it may be actually a variable band, or it may be disguised by denudation, but I believe the former is the more probable explanation.

The band of Dwyka Conglomerate runs between the main body of the Witteberg quartzites and an inlier of the same rock. The latter extends from two miles east of Prince Albert village through Baviaan's Kloof, De Gang, Kaffir's Kraal to Bosjeman's Poort. It bears a large river running down its centre, and the rivers that gather in the natural valley where the Dwyka Conglomerate occurs flow through the hard quartzite into this central river. The river runs in a syncline, which, though the depth to which it throws down the strata is not so great as that which the synclines on either side attain, that bring down the overlying Dwyka Series, yet owing to the latter rock having been squeezed out in the central one, the effective level is lower. At the head of the river a fine N-shaped syncline and anticline is shown; the dip-slopes facing south, and the escarpment north. North of this inlier, the Dwyka Conglomerate is again met with, in a similar manner tucked in under the quartzites; beyond this one gets the open Karroo. Almost the same thing occurs north of Klaarstroom, at Drogge Kloof, Fig. 4, but here the outer folds of the Witteberg quartzites are not separated from the main series by a band of Dwyka Conglomerate; at the same time, however, the folds make a point in the northern boundary of the Witteberg Beds, and a tongue-shaped slip of Dwyka rocks runs for some way in between the hills.

The road from Klaarstroom to the north goes through hills of Witteberg Beds, and some instructive sections are afforded, especially instances where the lower beds of anticlines meet at acute angles, and become less acute the higher the beds, till all effects of the fold are lost. To the east of the road, where it comes out of the hills, the Dwyka Conglomerate no longer dips under the quartzite, but the latter stands vertical, and is often wrinkled on a plane standing vertical to the surface.

The next poort through the quartzites going eastwards is Kando's Poort. Starting from the farm Matjes Vley, one comes at once to a tract of micaceous shales with quartzite bands containing *Spirophyton*. Little sharply-folded anticlines crop up from the flat ground and run in wall-like series east and west. Entering the hills, the quartzites increase and the softer shales become less apparent; the folding becomes more pronounced, or rather more of the folds are shown on the kloof-sides. Then comes a wide open shelf, thickly covered with red alluvium and soil, raised some two hundred feet above the general river level, and north of this are the hills. The red soil is characteristic of these valleys in the Witteberg and Bokkeveld Beds hereabouts, and is due to the barring up of the rivers by the intensely hard and compact banks of quartzite.

On the north of the hills there is an admirably exposed section of the shales below the Dwyka Conglomerate and a level surface on which the extent of the beds can be paced out, the dip of the beds being vertical.

SECTION NORTH OF KANDO'S POORT.

SHALES BELOW THE DWYKA CONGLOMERATE.

Top Witteberg quartzite	14	yards.
Papery black shales	87	„
Saccarine quartzite with cellular cavities filled with limonite	⅓	„
Papery, sandy, black shales	15	„
Thin-bedded, dense, white quartzite	10	„
The same, more massively bedded	11	„
Hard, green, non-micaceous shales	75	„
Black to greenish-yellow shales	40	„
Yellow sandstones and sandy shales	7	„
Greenish-black shales	75	„
Alternate black shales and thin sandstones ...	20	„
Yellow sandstones	5	„
Thin-bedded black shales	40	„
Yellow sandstones	2	„
Thin-bedded black shales	11	„
Yellow sandstones and sandy shales	7	„
Black shales	3	„
Sandstones and sandy shales weathering yellow...	21	„
Black shales	8	„
Sandstones and sandy shales weathering yellow ...	22	„
Shaly Dwyka Conglomerate, with small pebbles, and large ones more rarely; all well ice-scratched; pockets of quartzite	—	
Total thickness of Lower Shales	459⅓	yards.

The extent of the shales below the Dwyka Conglomerate is very large here, and increases still more on Zoetendal's Vley; this state of things is not normal, the shales being as a rule not half so thick, but they are all through very variable.

East of Kando's Poort, the Dwyka Conglomerate and the shales below run into a tongue which fills a narrow syncline in the Witteberg hills; north of the tongue there is a corresponding anticline of Witteberg quartzite, the point facing the west. Hitherto all the points of the anticline have been facing east, but from this place eastwards the reverse is the case, and as we shall see later, there are a number of these anticlines all pitching to the west in a series of points which lie roughly on a north-east line. The best illustration of what occurs is to imagine a sheet of corrugated iron, the ridges lying east and west; give this now a slight diagonal bend in a north-easterly direction, and let the lower portion be covered with water. The ridges in the corrugated iron will form a series of promontories projecting into the water much in the same way as the anticlines of the Witteberg Series do on the surface of the ground.

The further outcrop of the Witteberg Beds will be described in the section devoted to Zoetendal's Vley.

11. TYGERBERG.

North-east of Prince Albert village there is an anticline of Witteberg quartzite, surrounded with Dwyka Conglomerate, and forming the mountain called Tygerberg.

Between the Witteberg quartzites, near Prince Albert, and the Tygerberg, there is a wide valley, largely covered with sand and alluvium, and the succession of beds is not easy to follow. Ridges appear composed of brown quartzitic sandstones and shales, which are similar in some respects to the Laingsburg Beds of the Ecca, and at the same time look like some of the beds below the Dwyka Conglomerate. I believe the beds are entirely in the Ecca Series; their stratigraphical position indicates this interpretation, and the uncertainty about their appearance in the field must yield to this.

The White Band lying at the top of the Dwyka occurs skirting the conglomerate, and forms a conspicuous double line of kopjes. The black carbonaceuos shales weather white, and occasionally the pyrites in the rock gives on the surface large deposits of yellow and red ochres, due to the oxidization of the sulphide: the sulphur combines with the surface limestone to form gypsum, and as a further alteration, combines with the aluminium of the shales and the iron to form alum.

The following analyses by the late Mr. J. C. Watermeyer of the black shale will give an idea of the economic value of it:—

	Specific gravity.	Ash.	Fixed Carbon.	Moisture.	Volatile matter.
A	2.76	89.32	4.12	.88	6.68
B	2.40	87.60	4.04	1.40	7.96
C	2.71	93.05	1.67	.67	4.61
D	2.46	87.28	7.53	2.30	2.80

I think, in view of the great amount of tunnelling and shaft sinking that has gone on in the hopes of finding coal, that it should be as widely known as possible, that unless something very much more satisfactory than a shale carrying 7½% of carbon can be found on the surface, it is utterly futile to expect to get workable coal by going deeper. With regard to the gypsum too, and the ochre, it should be distinctly understood that these are surface deposits and that no quantity of them exists. The country is overrun with prospectors "from Johannesburg," who tell the farmers they have valuable deposits on their farms, and get options over the ground; the harm that these people do is very great, as the farmers thinking to sell their farms for a large sum, neglect their work and let necessary improvements remain unfinished. Those having farms on the "White Band" have been especially the victims of such people. The syndicates are seldom strong enough or foolish enough to take over the farms on the prospectors' report, and the farmers wait year after year for the fortune that never comes to them.

There are many peculiar rocks on this white band, one of the most striking is the grey fibrous limestone, known to the quarrymen in England as "beef," and the more solid ferruginous limestones containing bi-pyramidal crystals of quartz, as at Zoetendal's Vley. The chert band on the top of the shales is very constant; it is some 9 inches thick, and from its nature takes the sharp curvatures of the synclines and anticline very well, so that where these pitch upwards or downwards the chert band may be seen running out like the prow of a boat or of a boat reversed; beautiful examples of this last can be seen on the south border of the Dwyka Conglomerate a little to the east of Tygerberg Poort.

The inlier of the Dwyka Conglomerate with the White Band on top does not appear to cross the Gamka River, but eastwards it extends for a considerable distance, the White Band always running as a series of kopjes marked with peculiar white, yellow or red markings. These kopjes are known as Vuursteen (Flint) Kop, Wit Kop, and Asch Kop, names which sufficiently describe their nature.

The shales below the conglomerate are largely developed between the conglomerate and the top of the Witteberg quartzites. The top of the latter series is taken to be a very massive bed of white quartzite. Above this, though the shales have a great similarity with the shales occurring in the body of the Witteberg Series, nevertheless there are limestones and conglomerates which sufficiently distinguish these shales below the conglomerate from those in the Witteberg Series. They can further be distinguished from the shales above the conglomerate (the White Band) by their high content of mica, usually a very brilliant white hydrated mica, which is probably sericite. On the south side of Tygerberg Poort, these shales below the conglomerate are folded and contorted in a very complex manner; they contain certain beds of conglomerate, with a large amount of limestone and crystals of felspar, a rock which may easily be mistaken for the more gravelly portions of the Dwyka Conglomerate itself.

At the west end of the outcrop of the anticline of Witteberg quartzite there is a somewhat confusing state of affairs. Round the end, and separated from the main quartzite by a constant interval, there is a bed of brown quartzite; this is the bed that normally comes between the shales below the Dwyka Conglomerate and the conglomerate itself. At this place, however, there is conglomerate below it, and on the south the conglomerate rests directly on the main quartzites. On the north side there are black carbonaceous shales overlying the main quartzites, and these weather in exactly the same manner as the shales above the conglomerate, that is to say, they are coloured on the surface with brilliant yellow and red iron oxides, and white decomposition products; there is no question of their being brought into an anomalous position by folding.

The Witteberg quartzites occur in a narrow anticline, which has, as it were, been forced through the Dwyka Conglomerate, the latter rock forming " jaws " through which the more adaptable quartzite has been squeezed, just as lead may be forced between the jaws of a vice. The anticline is an upright one and has a tendency to fault on the south side; it measures eleven miles from end to end. The eastern end rises from a bush-covered slope as a perfectly symmetrical arch; the outside is formed of bare, curved slabs of quartzite; the arch rises rapidly and forms a considerable mountain, the crest of which is sinuous. The western end is not so striking. The poort, that is to say, the principal one on the west, exhibits a fine section of the knee-bend type of anticline, the top being flat and the limbs on either side straight but dipping 45° to the north and south.

North of the poort there is a tract of Dwyka Conglomerate, then the White Band, and then a further ridge of Ecca sandstone, all dipping steeply to the north. Beyond the Ecca ridge, there are shales worn to a flat, and then still further north a wide open plain thinly covered with sandy soil and slowly rising to the folded area near the gold-fields. An isolated outlier of the higher and more compact sandstone of the Ecca Series occurs on the west and forms a high hill called Blue Kop. These beds lie fairly flat, but on Ganna Vlakte one again comes to highly folded strata with vertical dips. The homestead on Waterval lies on an anticline and the spring south of the house rises in the anticline. The beds belong to the higher Ecca Series and consist of:—Sandstones weathering red; the same weathering yellow and breaking down to sand; limestones; and purple and blue shales.

North of this there is an immense farm marked on the map as Spreeuw Fontein and Tornitz Kraal which was proclaimed as a gold-field. The matter of the gold will be discussed later; stratigraphically the place is important as it is the first place going north where the Karroo reptiles are found. I have looked carefully myself and have made extensive enquiries from shepherds, etc., but can find no trace at all of fossil bones south of this place; one must therefore draw a line here between the Ecca and Beaufort Beds, although there is no lithological change to mark it by, and the beds are perfectly conformable; they also do not appear even to belong to a higher series as the folding and slight northerly dip of the whole conceals the true relationships of the beds.*

The southernmost localities of the Karroo reptilian remains are:—(1) Prince Albert Road Station: in a small rounded kopje between the double-storied house and the river on the north side (the site of a block-house during the war) there is a band of limestone that weathers out in rough brown blocks, and along the line of this the bones occur; they are in detached lumps and enclosed in hard limestone; no head has been found here. Being so near to the Railway Station a great number of vertebrae and limb-bones have been removed from time to time†, but they seem to be weathering out of the rock continuously. (2) Spreeuw Fontein. South of the old government office the greater part of the skeleton of a *Pareiasaurus* wanting the head was obtained for the Museum. (3) Klein Waterval, a farm comprising the eastern portion of Spreeuw Fontein. Above the house an entire pocket of bones occurs all of very large size. The bones are detached and lying in all positions in the rock; one skull was obtained here and is being described, some of the large bones belong to *Tapinocephalus*. (4) Zeekoegat. On the farm of Mr. Du Plessis, the Field Cornet, the greater portion of a *Pareiasaurus* was dug out here by the owner, and bones occur in a particular bed over a distance of two miles. Joining these points we get a sinuous line representing the southernmost limit of the Karroo Beds; how the line is continued to the east we do not yet know but it probably turns north along the boundary of the Beaufort West Division, as directly east of Zeekoegat in the Willowmore Division, we get an entirely different formation, the Mottled Ecca or Graaff-Reinet Beds in which up till now, no fossils have been found.

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* For a discussion on Mr. Dunn's unconformity beneath the Beaufort Beds, see Ann. Report for 1902 (p. 104); Prof. Green's unconformity at Aberdeen has not been investigated yet.

† Some of them were removed by Dr. Philippi of the German South Polar Expedition.

The outcrop of the White Band and Dwyka Conglomerate east of Tygerberg runs east in a straight line to within a few hundred yards of the homestead Vliege Kraal, the first farm in the Willowmore Division. I have not noticed any rocks which could be placed in the Witteberg Series in this anticline as shown in the map accompanying Mr. Sawyer's Report*.

At Groot Sleutel Fontein a further anticline is started bringing up the Dwyka Conglomerate through the Ecca Beds; at the commencement it forms a knotted hill called Noorse-doorn Kop, and thence runs eastwards in a series of kopjes and broadens out on Fisch Gat. The northern boundary of the outcrop is important owing to the conglomerate which acts like a dyke to the underground water flowing southwards; springs occur all along this line as at Minnies Kraal, Strydom's Vley and Klein Loerie Fontein. The extension of these anticlines will be described in the section dealing with Zoetendal's Vley.

III. ZOETENDAL'S VLEY AND SWANEPOEL'S POORT.

Under this section is included the country on the same line as Tygerberg, but which lies east of that part of the country and north of the Witteberg Hills. The rocks are Witteberg, Dwyka and Ecca Beds, but the last have certain peculiarities, and I have called them the Graaff-Reinet Beds.

The farm Zoetendal's Vley lies near the eastern corner of the Willowmore Division. The two homesteads stand the one on Dwyka Conglomerate the other on alluvium covering the White Band. Springs come out of the river-bed for some way from the first outcrop of the conglomerate, and on the actual junction a large well has been dug in which there is a never failing supply of good water. South of the homestead there is a short tract of Dwyka Conglomerate, then foot-hills of the mountains composed of micaceous shales below the conglomerate, and finally the flat-topped mountains of Witteberg quartzite. The last have the strata standing vertical and the crushing and crumpling has taken place on a vertical plane.

The greater part of the Traka or Maiden River passes through Zoetendal's Vley and the poort through the Witteberg hills is very narrow. There is a sharp anticline and syncline, the latter bringing the Dwyka Series down to the level of the river. The folds are straight sided, and the limbs meet at acute angles, like the sides of a roof; as there are soft shales in among the quartzites these easily weather out and leave the quartzites exposed in long dip-slopes which are usually covered with Spek-boom, Noorse-doorn and aloes.

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* Report on the Mineral Resources of Prince Albert, Cape Town, 1893.

East of Zoetendal's Vley the outcrop of the Witteberg quartzites doubles back on itself twice in the form of an S, a tongue of Dwyka Conglomerate running up the lower loop of the S, and a tongue of Bokkeveld Beds up the higher. North of this again, a tongue of Dwyka Conglomerate separates a further series of Witteberg folds from the main band, and the points formed by the anticlines pitching west lie on a line running approximately north-east; it is as if there were a general dip to the north-west carrying all the other folds with it.

North of Zoetendal's Vley there is a long outcrop of shales below the Dwyka Conglomerate, in which the quartzites in these beds are largely developed. It is very easy to mistake the quartzites for those of the Witteberg Series, but the following characters render the confusion only temporary. (1) The conglomerate lies directly on the quartzite without shale between. (2) There are limestones in them. (3) They occasionally turn into peculiar felspathic conglomerates. The quartzites run in long lines of kopjes as the rock is so much more resistent than the surrounding strata. To the east of Zoetendal's Vley the anticline that brings them to the surface pitches slightly to the west and the quartzites become cut out; it is characteristic of them that even on two sides of the anticline the nature of the rock is often widely different. In this locality the peculiar conglomerate just mentioned occurs; it is composed of angular fragments of quartz, stained brown on the surface, but blue when unweathered, in which are set numbers of limestone spherules varying in size, but never much more or less than an inch in diameter, water-worn quartz-pebbles, both black and white, and more rarely large crystals of felspar. The whole rock is often very porous, large interspaces occurring between the angular grains, but in spite of this it is tough and weather-resisting. The limestone spherules when broken across and weathered show centres and concentric rings of harder material, but they are not organic.

In the limestones in the shales there are frequently stems of plants like sedges, and the rock itself is stained black with carbonaceous matter.

The Dwyka Conglomerate over this area is quite normal in character and does not appear to be very thick; it is difficult to estimate the thickness in such a disturbed area as this, but I think 500 feet is sufficient to explain the outcrop.

The shales above the conglomerate weather into the typical White Band; to the south the chert band on top is not very noticeable, but to the north and east it is more constant.

In the Zoetendal's Vley area there lies on the White Band a series of sandstones and shales, which are characterised by a spotting or mottling; the ground colour is blue or greenish-grey, with white spherical marks about the size of a pea. This kind of rock is found at Graaff-Reinet and in all the country to the south of the town, round Kendrew, Adendorp, etc. I propose, therefore, to term these the GRAAFF-REINET BEDS. We found the same kind of rocks at Kei Road and Kentani,* but the intervening country has not been mapped, so it is impossible as yet to correlate these latter with the Graaff-Reinet Beds. Further to the east of Zoetendal's Vley the Graaff-Reinet Beds rest directly on the conglomerate, and the White Band, here scarcely recognisable owing to the absence of carbonaceous shale, is found in this series with some three hundred feet of the mottled rock separating it from the Dwyka Conglomerate. Strictly speaking, the Graaff-Reinet Beds should count from the top of the White Band just as the normal Ecca Beds do, but the rock above and below is so much alike that it is best to count right from the top of the conglomerate.

The Graaff-Reinet Beds consist of shales and sandstones, marked with a white spotting or mottling on a blue or greenish-grey background; they contain a large amount of silicified wood and some quantity of limestone; this latter is penetrated with thin veins of chert and weathers out on the surface in small irregular lumps, on which the chert often forms a lace-like or fretted pattern. The area of the beds is as yet unknown; they commence sufficiently suddenly on the west, and are very markedly different from the normal or four-phase Ecca† with which they were contemporaneous. The Graaff-Reinet Beds not only take the place of the normal Ecca along the same strike, but they wedge in between the normal Ecca and Dwyka Series. The Laingsburg Beds occupy a similar position in the west. These two series of beds only represent zones in certain areas, and their place is taken in another area by a different set of strata which are strictly contemporaneous: they represent basins of deposition, and are more correctly spoken of as Ecca Beds of the Laingsburg or Graaff-Reinet "facies."‡

At Zoetendal's Vley the Graaff-Reinet Beds are typically developed, but owing to the small exposure between the Dwyka outcrops they are not conspicuous. They certainly continue as far as Zout Kopjes to the west, but beyond this they merge without perceptible change into ordinary Ecca. North of Zoetendal's Vley they are met with overlying the White Band, and near the main road, the sandstones make a small line of kopjes in which the rock is very well jointed and full of large nodules of limestone from three to six inches in diameter. On the north of this particular outcrop of Graaff-Reinet Beds one is not so sure of their distinction, as there is a large quantity of black shales. In the centre of the area, at the farm Slabbert's Poort, there is an anticline in the sandstone which is really the continuation of the Tygerberg anticline, and springs issue all along this line. The eastern portion of the area lies on Kruid Fontein, but a heel is given off towards Blydeberg, and a small outlier, the continuation of the heel, runs eastwards through Wittekops and Vogelstruis Leegtes.

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* Ann. Report, 1901 (p. 28 and pp. 53–54).

† The four phases are—1, Sandstones weathering yellow; 2, Sandstones weathering red; 3, Limestone; and 4, Shale.

‡ Ann. Report, 1901 (p. 28).

Blydeberg is a double anticline of Dwyka Conglomerate; looking northwards from the crest, one has a view of the flat Karroo, an immense tract of slightly undulating ground covered with sandy soil and drained by the Salt and Kariega Rivers. In the far north the escarpment of the watershed stands out in clearly defined blocks of mountains, separated by intervals where the streams have cut back. The mountains are dolerite-capped, and are known as the Beaufort West, the Nel's Poort, the Camdeboo, the Aberdeen, and the Tandjes Bergen (Graaff-Reinet) blocks.

The rocks underlying these plains in the Willowmore part of them belong to the Graaff-Reinet Beds, and I found the same was the case at Kendrew, at the eastern end, so presumably the whole of them is on that formation. The surface is well covered with good Karroo bush, but the soil is thin and sandy, so that the least wind forms a number of sand columns, a dozen or more of which may be seen most summer afternoons arranged in a row and towering high into the air. The harder portions of the underlying rocks, or rather such as have not a tendency to break down into sand, lie about the surface, and are composed of silicified wood, limestone with chert, chert, and hard fragments of calcareous sandstone. These fragments have a typical sand-etched appearance, like those found on the plains of Hope Town. The whole district here, in fact, closely resembles the flats of Hope Town, and the same low grade streams occur in both, giving rise to "kuilen," that is, natural dams or lakes, along the river courses: the vigorous downward cutting of the rivers, to a great part due to overstocking and consequent trampling of the veld, is rapidly making these "kuilen" disappear, except where they have been saved artificially by weirs, but an additional cause is the modern increase in the fall in the rivers, due to the rise of the continent.*

Over the watershed of the Salt River there is a marked difference. Here there is the kopjes—or randjes—veld of the

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* It is interesting to notice that there is a small snail-shell living on the Karroo bushes in the flats. Mr. Lightfoot has identified it as *Zingis trotteriana, Benson*, a species found also in Oudtshoorn and Knysna. It is not the sort of animal one would expect to find in such a very dry region; my specimens came from Vley Kuil.

Gouph, where the fall of the rivers is too great to allow them to cut sideways; the rocks, too, are of the four-phase Ecca type, and this partly accounts for the difference. Looking at the courses of the two river systems, the Gouritz and Gamtoos, to which the streams on either side of the watershed belong, the former run straight for the mountains, and cut through them in the shortest diameter across the strike,[*] the streams on the eastern side of the watershed, however, drain into the Groot River, which runs as far as Steytlerville in the mountains of Witteberg quartzites, parallel to the strike, and in a direction in which erosion can have least effect.

Commencing the description of the flats from the west, we find the boundary-line between Willowmore and Beaufort West lying on the edge of the kopjes veld or the watershed between the Gouritz and Gamtoos Rivers. At Schiet Kuil and the north part of Vliege Kraal the four-phase Ecca lies on the White Band, normally, and is penetrated with white quartz veins; at Commando Kraal there are many veins filled in with quartz, often yellow, but in which deposition has not advanced sufficiently to fill the vein entirely, so that the quartz vein is "drusy" or full of interspaces between the sharply-formed crystals. Over the northern boundary of Commando Kraal, prospecting shafts have been put down, but as far as I can learn the gold found has been all alluvial; for a discussion on this question see later (p. 136).

The four-phase Ecca continues over Rensburg's Kuil, Puts and Schiet Kuil (re-named Honde Kuil), the sandstones on the last place being full of indeterminable plant-stems; east of these places the ground sinks away, the four-phase Ecca formation making a low ill-defined escarpment as if it lay upon the Graaff-Reinet Beds. The latter, however, come up to the White Band on Koren Kraal; one is less certain at Vley Kuil whether the rocks lying on the White Band are four-phase Ecca or Graaff-Reinet Beds. North and eastwards lie the wide plains which stretch to the foot of the dolerite-capped escarpment of the Camdeboo Mountains. At Beer Vley the White Band becomes separated from the top of the Dwyka Conglomerate by a considerable thickness of Graaff-Reinet Beds, the latter lying directly on the conglomerate. A syncline in the Dwyka Series under the mountain brings down a strip of White Band in the middle of the conglomerate, and this runs eastwards from Beer Vley to Swanepoel's Poort and Koenie Kraal, in the Jansenville Division; the more northern band disappears under the red sand, and altogether is doubtful in its position, a wide strip of it lies between Grobelaar's Kraal and Vogelstruis Leegte.

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[*] A. W. Rogers, Geol. History of the Gouritz River system, Trans. S. A. Phil. Soc., Vol. XIV., Part IV.

Inliers of the White Band occur once more under Schoorsteenberg and to the north of Koenie Kraal, which lie respectively north-west and north-east of Swanepoel's Poort. Schoorsteenberg is composed of Graaff-Reinet Beds, lying to the south of a whale-backed anticline; it forms half the circumference of an amphitheatre, the rest of the rim having been denuded away, while the centre of the amphitheatre is occupied by the inlier of Dwyka Conglomerate and White Band; the other inlier is of the same nature. The White Band here is typical, with carbonaceous shales, chert, limestone and surface deposits of ironstone and gypsum.

Between Vogelstruis Leegte and Swanepoel's Poort there is a very rugged country, formed of Witteberg quartzite folded into acute bends, which often bring down the Dwyka Conglomerate to a level with the rivers in the kloofs. The folding is east and west, but a north-easterly superimposed folding cuts off the various outliers of Dwyka Conglomerate, and brings the long east and west valleys to a termination (Fig. 5). The whole series of hills have been cut to a level about 3,500 feet above the sea; but in most cases the crests of the anticlines alone reach this height; still, some considerable flats do remain on top, and form invaluable gathering ground for rain water. In most cases the rocks are folded into the form of pent-roofs, down which all the rain water rushes impetuously, and very little is held up. The Groot River, as mentioned above, flows through the centre of this range in a syncline; the shales below the Dwyka Conglomerate, the conglomerate itself, and, to the east of Waai Kraal, the Graaff-Reinet Beds with the cherts and limestones of the White Band as well, are all represented in the valley; one gets, therefore, the curious phenomenon of an elevated tract of country running east and west, into which, from the lower country on either side, from the north equally with the south side, a number of lateral streams run through big poorts. Those coming from the south have to pass over the shales below the Witteberg quartzites, and in doing so take up a great deal of salt—in fact, the stream which comes through Vleder Muis Poort is pure brine: this is a great misfortune to those living along the Groot River, as when the river is low or stagnant, these brine springs run in and spoil the little water available.

The streams coming from the north have a much larger drainage area: before entering the Witteberg quartzites their waters formerly were banked up, and extensive vleys were formed; the two occurring in our district are Beer Vley and that at Swanepoel's Poort. The latter, which was the larger, but was drained at an earlier date, shows on the present river banks a thickness of 15 feet of sandy soil cemented with lime. A great number of shells are said to have been dug out in the soil about the poort, but the only one shewn to me was a marine form, *Patella rustica*, evidently brought from the sea-coast by natives; but Mr. Miller, of Swanepoel's Poort, has a small elephant's skull which had recently been dug from the calcareous soil, buried some six or eight feet. I do not think the elephant's skull indicates a great age for the deposits; they could have existed in this place till comparatively recently, as there is an abundance of "Olifant's Koss," a succulent shrub, otherwise known as Spek boom (*Portulacaria afra*), of which the elephants were very fond, and Knysna, where they still live, is not very far away: Koodoos also live in these mountains. As regards the flora, it is interesting to notice that the Sepree *Widdringtonia cupressoides*, Endl. (or *Callitris arborea*, Schrader*), a common shrub in the Cape Peninsula and on the coast ranges, grows on these semi-Karroo hills, and many of the Proteas, such as *Leucodendron abietiforme*, and healths as well; I think this inland extension of such typical coastal plants is

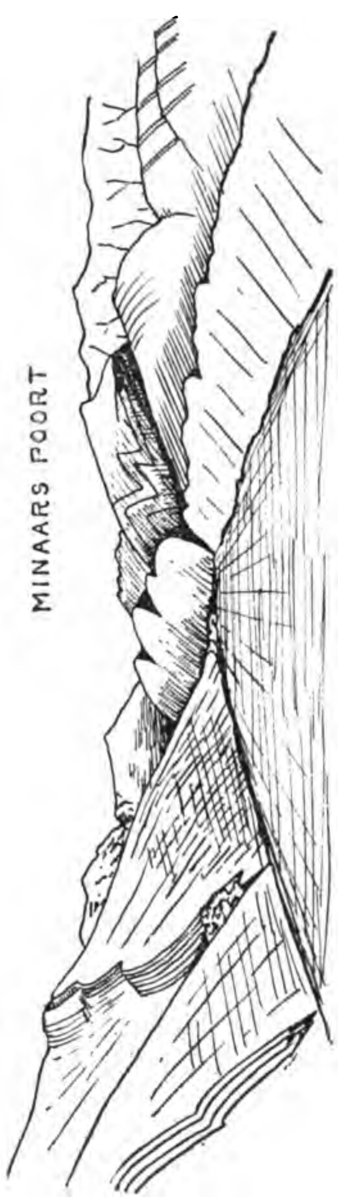

FIG. 5.—View from Vogelstruis Leegte, looking towards Windheuvel, showing the Witteberg Beds dipping on either side beneath the Dwyka Series. Groot River heights in the distance on the right, and Beer Vley Mountains on the left.

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* There is some doubt as to the species, as the Willowmere trees grow to a height of 50 to 80 feet and more, while the limit of the Cape ones is 10 to 12 feet. It is not the Cedar, *W. juniperoides*, and may possibly be an undescribed third species.

due to the plateau, of which there are remnants on top of these mountains, having formerly been connected with the coastal ranges, forming, in fact, part of their slopes. In another sense the flora is interesting geologically, as it is at the longitude at Swanepoel's Poort that the first Kaffir bread-tree, *Encephalartos caffer*, one of the Eastern Province cycads, occurs, with the Elephant's foot, *Elephantorhiza burchellii.* Among birds, too, the metallic spreeuw, *Lamprocolius phoenicopteris* takes the place of the yellow-wing *Amydrus moria,* and we shall see later that in Baviaan's Kloof the tree-euphorbia (*E. grandidens*) reaches as far west; no doubt, a botanist or zoologist would find many more instances of eastern plants or animals coming in at this meridian for the first time going towards the east, but I have only mentioned the most striking examples; it indicates that the Gamtoos and Gouritz river-systems are very ancient, and have each acquired a particular fauna and flora, or, at any rate, that their mutual watershed forms a boundary between many eastern and western forms; one can notice that the western or more arid types are encroaching on the eastern.

The Beer Vley Poort has been long looked to as a suitable site for storing water. Barrow camped at the place in 1797, and describes it as one vast meadow covered with herbage, knee deep; the two streams that come together here were running at the time, the Kariega with muddy but fresh water, and the Salt River with water little different, Barrow says, from ordinary sea-water. In 1860* all the herbage had disappeared, but the Kariega ran continuously from December to May; in 1880 the water was restricted to short floods three times a year; last year it had been dry for 15 months before the flood came.

The width of the poort is 1,000 feet, the anticline of the Witteberg quartzite through which the river has cut its way pitches underground a little way to the west, and the river, if dammed up in the poort, would find its way out round the point of the anticline; the calculated area of water-surface, should the dam wall be carried to such a height, is 18 square miles, with a maximum depth of 80 feet. The lower end of the poort opens into the flats of Windheuvel, and then the river plunges straight through the highest point of the Witteberg hills or Groot River Heights, as they are called, through Minnaar's Poort (Fig. 5), whence it issues into the long valley of the Groot River between Smit's Kraal and Steytlerville. The difficulty connected with the work is the amount of brine carried down by the Salt River; the Kariega, having a greater fall, does not seem to collect so much. When a river like the Salt River passes for most of its distance over flat country, where the water is stagnant or at best very sluggish, "zeekoegats," or large pools, are formed, where it evaporates, and the salt in the water, which is inappreciable after rain, becomes concentrated till the solution is actual brine; it should not be very difficult, however, to turn the Salt River, so that it joins the Groot River below the dam, and if this were done, the only valid objection to a work of the utmost public utility would be overcome.

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* Report of the Hydraulic Engineer for 1880, Cape Town 1881.

IV. WILLOWMORE.

The strip of Bokkeveld Beds that we saw coming from Prince Albert, between the Table Mountain Sandstone on the south and the Witteberg hills in the north, on approaching the village of Willowmore, widens out, and acquires an individuality of its own.

The Table Mountain Sandstone of the Zwartebergen we saw disappeared underground close to the Willowmore-Uniondale Road. On the other side of the road there is a krantz of sandstone dipping south, which runs east-north-east, the sandstone increasing in volume as it is followed eastwards: this is another crushed anticline of Table Mountain Sandstone, and is called the Zuurberg; it is separated by a narrow isthmus of Bokkeveld Beds from the sandstone of the Zwartebergen. The increase in bulk reaches its culmination at the Zuurberg beacon, east of which it suddenly contracts, and is continued as a thin slip of sandstone, nowise more important than the upper sandstones of the Bokkeveld Beds in the less disturbed regions of the west. This is at Klein Grobe,* 8 miles from Willowmore. Eastwards, a small anticline comes up from underground, joins with the narrow prolongation of the Zuurberg, and the two together swell into a considerable whale-backed anticline, nine miles long by two broad; on the north lie Koegeroo and Vaal Fontein, and on the south, Doorn Bosch and Knorhaan's Vlakte. At Koegeroo in the lower grey micaceous shales of the Bokkeveld there are a number of well-developed fossils, large *Homalonotus herscheli*, *Leptocoelia flabellites* and *Spirifers;* the rock and fossils are identical with those found in exposures on the same horizon in the Warm Bokkeveld, in the extreme west, for instance, at Gydow Pass and Uitkomst in Ceres.

The eastern end of the whale-back, where the anticline pitches beneath the surface, there is the usual amphitheatre of Bokkeveld Beds capped with the second sandstone facing it. There is another whale-back of Table Mountain Sandstone a couple of miles to the north of this one, which I shall come to directly; I want to describe the southern limit of the district first.

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* The local names of the farms have mostly been changed since the material for the map of the Division was obtained; I give only the map names.

A little further down the pass from where we saw the Zuurberg sandstone begin, there is another long ridge of sandstone, this time a folded one with a pitch to the east; the fold is an anticline, but a portion of a syncline is included as well, and its upturned beds are broken off by a fault. The anticline is also crushed, so that both limbs exposed on the surface, dip south To the south of this strip there is the Anthonie's Berg, and between the two is an elevated terrace filled in with Bokkeveld Beds, the narrow strip of Table Mountain Sandstone forming, as it were, a wall, banking in the softer shales behind it. The narrow anticline near the toll house merges into a series of sharp anticlines, the lower of which have the troughs between them still filled with Bokkeveld Beds, the eastern face of this series shows on the surface as a number of short tongues of Table Mountain Sandstone projecting into the Bokkeveld Beds; on the east, however, on the farm Georgida, there has been an excavation, either by faulting or by detrition, and a vertical cliff has resulted. Originally Enon Conglomerate was piled against this, but there is a good deal of it now standing clear, thus exposing a section of the internal structure of the mountain; the Table Mountain Sandstone is shown thrown into a number of folds mostly upright, but on the south there has been more crushing, and both limbs dip south.

East of this the sandstone rises, to form the mass of the Anthonie's Berg, a very considerable mountain, but of short length, for the main anticline of which it is formed pitches as rapidly east as it rises from the west. The eastern termination is similar to the western, only that the anticlines forming tongues projecting into the Bokkeveld areas are larger and longer. One of the tongues is turned sharply to the north-east, and can be followed down the river valley towards Ganna Kloof. Parallel with this there is an inlier of sandstone, shaped in the same way, but entirely surrounded by Bokkeveld Beds; this is on Vaal Water, and on the southern isthmus of slates another road is carried from the Olifant's River valley into the little Karroo of Willowmore. East of this again there is another flat area, formed by wrinkled Table Mountain Sandstone; and then finally the sandstone rises into a continuous mountain range, the Baviaan's Kloof Mountains.

Anthonie's Berg lies, therefore, on the line of the great inner range of coast mountains, yet is separated from the Zwartebergen in the west and the Baviaan's Kloof Mountains on the east by neks still retaining Bokkeveld Beds. This is not merely a chance coincidence, but is due to a general folding in a northerly or north-easterly direction which is super-imposed over all those already existing; a folding which will be found later in treating the Olifant's River Valley and that of the Baviaan's Kloof to have involved the Enon Conglomerate, yet which had finished before the plateau-cutting had begun, as we find the Enon Conglomerate folded by this system of folds, and levelled off equally with the earlier formations. The northern edge of the Baviaan's Kloof Mountains commences in a north-easterly direction, and then turns east and continues in a fairly straight line a little south of east. The northern face of the mountains is steep and cut into narrow kloofs, while the sandstone is much wrinkled. The southern face of the mountains looks on the flat plateau in which the Baviaan's Kloof lies.

North of Koegeroo one enters a poort cut through sandstone, which is evidently the Second Sandstone of the Bokkeveld Series; emerging from this there is a long whale-backed anticline of Table Mountain Sandstone, extending from Brak Fontein to the eastern boundary of Dassies Fontein, a distance of nine miles; on either end there is the usual amphitheatre of shales, capped with the Second Sandstone.

North of the house on Brak Fontein, again, there is a small anticline projecting through the Bokkeveld shales, but the whole surface of the Table Mountain Sandstone is covered with a thin layer of shale, so that the older formation cannot really be said to reach the surface. For the rest of the Willowmore area of Bokkeveld Beds, their extension is due to folds which do not bring up the underlying Table Mountain Sandstone.

The one member of the Bokkeveld Series that can be recognised is the Second Sandstone, which is constant and very thick; whether the other sandstone beds are present is doubtful, but even in the typical section along the Gamka these were thin compared with the second; the respective thicknesses there were:—

Fossiliferous or 1st Sandstone	145	feet.
First White or 2nd Sandstone	419	„
Second White or 3rd Sandstone	85	„
Third White or 4th Sandstone	100	„

Thin beds, such as the sandstone bands other than the second, become unrecognisable when intensely crushed. To the south and east of Willowmore Village there are a great number of sandstone ridges, some showing folds and thrust faults in the sections in the kloofs, others lying apparently undisturbed or dipping at moderate angles to the south; I believe the ridges in which this sandstone occurs all belong to the one and the same bed repeated by folding. The waters flowing from the Zuurberg get banked back by these sandstone ridges, and inclined plains are produced covered with red clayey soil. Rain-water falling on these plains to a certain extent sinks in, and part of it coming to rest on the junction of the soil and rock flows down towards the ridge, and tends to come out as a spring in the poort. That it did so on a large scale formerly is shown by the great amount of limestone deposited from solution in water that one gets in the upper ends of these kloofs, for instance, in the kloof three miles from the village, along the Baviaan's Kloof road, where all the lime used in building in Willowmore is obtained; the pressure of water now is very small, and unless the water is artificially brought to the surface, it filters away underground.

The village of Willowmore lies on one of these plains, and it is remarkable that even in this last drought the wells in the red soil afforded a constant supply all through; the water is brak, but on going into the rock beneath, fresh water is often obtained, or the water may be charged with sulphuretted hydrogen, which, however, soon disappears when the water is allowed to stand. To the north-east of the village there is a very wide plain, covered with this red alluvium, between the hills of folded Bokkeveld Beds on the south and the Witteberg quartzites on the north. The soil is fertile and supports good Karroo bushes, but when overstocked, the sand that is raised by the wind kills off the green shoots; it is said to be too brak for irrigating, but that is a matter of management.

To the north-west of the village there is a high hill called Aasvogel Berg (4,400 feet), formed by Witteberg quartzite; its southern face in a knee-bend, but it has been worn away in a precipitous krantz; a line of similarly made hills extends north of this, from Wit-kopjes through Paarde Poort, Vleder Muis Poort, Waai Kraal, and so on towards Steytlerville, and is connected with the Aasvogel Berg by a bending back of the outcrop of the Witteberg Beds, as previously explained.

On the outer or southern side of the Witteberg quartzites there is a zone of shales highly micaceous and gritty; occasionally it becomes carbonaceous, as on the south side of Leeuw Kloof Poort, and makes a third and lowest zone, in which these carbonaceous shales exist in the district. In Bredasdorp similar carbonaceous shales exist, which may be the equivalents of the Willowmore ones. At Victoria Bay, in George, carbonaceous shales occur in the Malmesbury Beds, so that it is evident that they are characteristic of no particular age or horizon in South Africa.

V. THE OLIFANT'S RIVER.

The geology of the Olifant's River as far as Vlakte Plaats was described by Mr. Rogers and myself in the Report on Oudtshoorn published in the Annual Report for 1898. The present survey began from Vlakte Plaats, and was continued to the end of the valley, another fifty miles to the east.

At the south of Meiring's Poort we found Cango Beds lying unconformably beneath the Table Mountain Sandstone, though the latter apparently dips beneath the former. The Cango Beds consist of clay-slates and phyllites, occasionally crinkled into small folds, but mostly lying quite straight and dipping at angles from 45° to 60° south. There are three or four bands of conglomerate in the slates, which from their harder texture weather in ridges; they are accompanied by a friable micaceous sandy phyllite. The pebbles are interesting; they have been intensely crushed, and have acted like semi-plastic bodies, sometimes yielding to the pressure, at others breaking with granular fractures; the commonest stone is white or black quartz, but a hard black slate or lydianite is also common; tourmaline-granite was also found, which is remarkable, as there is no granite outcrop at present anywhere near. There are many white quartz-veins in these beds; some are covered with a greenish material which is possibly epidote; at any rate, the green is not due to metallic substances.

At Buffels' Vley a thin strip of Table Mountain Sandstone becomes wedged in between the Cango clay-slates and the Enon Beds, due to a fault hading south, or occasionally, as at Jager's River, perfectly vertical, so that but a small portion appears at the surface. The thin strip of sandstone is continued past Vlakte Plaats, Loopende River, Schoongezigt, Vooruitzigt, Wilge-Boom, and Jager's River. On the eastern end of this last farm the sandstone of the outer strip joins with the main mass, and the Cango Beds pass under the arch of the anticline. It is this anticline that continues the line of the Zwartebergen to their termination. The western end of the anticline which lies in the Ladismith Division was described in the Annual Report for 1897.* The Cango Beds there pass under the Table Mountain Sandstone in exactly the same way; between this point which is on the farm Wilgehout's River and Jager's River, a distance of 75 miles, lies the Cango district, entirely made of Pre-Cape rocks. On the seaward side of the Langebergen, from Worcester to Swellendam, for some 90 miles, there is a similar stretch of Pre-Cape beds, bounded on the south by a fault: here, however, the Table Mountain Sandstone does not arch over the older rocks in such an unmistakable way, and the nature of the closing-in of the older beds is obscure. Looked at broadly, these exposures of Pre-Cape rocks and their faulted boundary can be read thus:—Starting from the interior of the Continent, we get Beaufort, Ecca, Dwyka Beds, and so on to the Table Mountain Sandstone and the Pre-Cape rocks, then a fault; after that come Witteberg, Bokkeveld, Table Mountain Beds, Pre-Cape rocks, then again a fault; finally we get Ecca, Dwyka, Witteberg, Bokkeveld, Table Mountain Beds, Pre-Cape Rocks, then the sea. This represents an imbrication of the crust, of which the scales dip inland and the escarpments face the sea, the whole being obscured by the want of rigidity of the rocks when subjected to strain in large masses and their consequent bending and folding.

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* Cape Town, 1898 (p. 61).

The upper basin of the Olifant's River is surrounded by mountains of Table Mountain Sandstone. Standing on any of the high points in the upper basin of the Olifant's River, one is at once struck by a line running all round under the mountains, as if the whole had once been a lake, and these terraces, high up on the mountain side, were the beaches left on the withdrawal of the water. The idea is further strengthened by finding that on the ledges one does get veritable gravels, such as might have been formed on a lake-shore. The matter, however, is not so simple, as these gravels and the plateau they rest on at one time extended continuously over the whole area, and the present river has cut its basin out of this former plain. Another point, and one on account of which I have introduced the subject at this place, is that along the northern rim of the hollow the boundaries are dip-slopes of Table Mountain Sandstone. A little Bokkeveld slate still clings to them and the Enon Conglomerate* to some extent lies piled against them, but the greater part have been cleaned by denudation, and exhibits bare rock-faces; the dip-slopes dip at high angles to the south, and are truncated on top by the terrace and covered with gravel. The Enon Conglomerate does not dip parallel with the Table Mountain Sandstone, but the beds abut abruptly against the dip-slope, as if the conglomerate was in the position it occupied when it was first laid down. The folding of the Table Mountain Sandstone therefore took place previously to the deposition of the conglomerate.

At Jager's River the dip-slopes occur in the outer strip of Table Mountain Sandstone, and the Cango Beds behind the fault, being softer than the sandstone, have weathered away to a considerable extent, but at the same time portions of them have been protected by the gravel cap. There is a well-marked band of banket in the sandstone, similar to those along the Homtini River in Knysna. On the north of the clay-slates the Table Mountain Sandstone dips at very high angles, 70°-90° south. The kloofs in these mountains are extraordinarily narrow and deep, far more so than the usual ones in the district, and they are surpassed only by the Baviaan's Kloof side-streams, a fact which can perhaps be explained by the Olifant's River having been aided in its downward cutting by folding that has let down the conglomerate, so that the steepness of the fall of the side streams is unnaturally great; if there had not been some action of this sort, it is difficult to understand how it is that in the area between the Kammanassie and the Zwartberg Ranges, the Olifant's River lies near the northern limit of the valley, instead of taking a more or less central course.

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* I believe the beds here referred to are really the bottom group of the Uitenhage Series and therefore are properly called the Enon Beds.

The boundary of the Table Mountain Sandstone runs east-north-east from Jager's River to Tover Water's Poort, and from here due east. There has been some crinkling of the strata in the bend, and for a short way east of the poort vertical exposures of small broken folds parallel to the east-north-east strike, appear on the face which ends the foot-hill; it is on the line of one of these broken folds that the "Tover water"* issues, a hot spring which has a temperature of about 120°. The water comes up in a round pool from the gravelly bottom and sides, of which the little "eyes" of the spring comes out. It contains in solution a considerable amount of iron, and is slightly tinged with sulphuretted hydrogen. The deposit from the spring water is massed up all round, and the furrow that has been cut through it to let the water flow down to the farm gives a good section of it. The deposit when wet is a chocolate-coloured sinter, sometimes with bright crimson or yellow streaks; but when it is taken out and dried, it crumbles at the least touch to impalpable powder. All objects floating in the water, such as sticks and weeds, become coated with the brown flocculent precipitate. The spring is much resorted to by invalids of all descriptions, but there is no suitable accommodation for them at present.

In the kloofs to the west there occur masses of sintery ironstone, such as might have been formed in a similar way, and it is highly probable that at some previous time there were several hot springs along this face of the mountains, but the conduits have been blocked up by the deposit.

At the end of the Zwartebergen there is the Zuurberg Poort, through which runs the road from Willowmore to Uniondale. The Table Mountain Sandstone dips 45° south, and the outcrop of the Enon Conglomerate recedes from contact with the sandstone. At first in the kloofs near the boundary some black and grey shales of the Bokkeveld Beds appear beneath the covering of Enon Conglomerate, as at Vaal Krantz, but nearer Georgida, the Bokkeveld Beds are exposed on the surface. They contain a good many fossils; along the river near the Toll house there are nests of gastropods, and a few brachiopods and lamellibranches, but higher up the pass some fine crinoids and trilobites occur.

On the east side of the pass there is the Anthonie's Berg,† with a southern boundary running a few degrees south of east to meet the range of hills that come from Uniondale in a east-north-easterly direction. The ledge cut in the sandstone about here extends into the Bokkeveld Beds also, that is to say, the dip-slopes here have not been so well exposed as further west; the level of the valley rises gradually eastwards to that of the ledge, and eventually, on the watershed, lies on it. The watershed, then, of the two great river-systems, the Gouritz and the Gamtoos, is not on a ridge of hills or mountains of which there is such an abundance about here, but on a strip of flat ground very much below the level of the adjacent hills.

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* Dutch for Magical Water.

† It may be of local interest to notice that J. van Reenen on returning from his historic journey in search of the survivors of the Grosvenor in 1791, passed through from Erenkroon on the Groot River, to the farm of one Antonie Nortier (Nauchee), evidently Georgida, for eight hours further on he came to the warm spring above the Olifant's River, Tover Water; I think it must be this Antonie Nauchee that gave the name to the mountain.

The range of hills to the south of Anthonie's Berg is part of the Kouga Mountains. It runs east-north-east, and faces the part of the Zwartebergen from Jager's River to Toverwater's Poort, which on its south face has the same strike. The crests of the mountains lie far back from the bed of the Olifant's River, but between there is a region, in which there is a great deal of Table Mountain Sandstone. This latter rock is intensely folded, and the crests of the folds appear through the overlying Bokkeveld Beds in long shreds and strings, often traceable only in the deep cuttings of the river channels, but often again running together and forming small hills for short distances. One such range of small hills constitutes the Oude Post Berg and Dwaas Berg, which shuts off a valley of Bokkeveld Beds from the Olifant's River; it is certain that at some previous period this Bokkeveld valley was drained by the Kammanassie, but whether owing to movements of the crust or by simple erosion, the Olifant's River has stolen this drainage area from the Kammanassie, and has left the small streams running in what appear to be most extraordinary courses.

The whole of this area was cut to a level plateau, and covered with gravel to a depth of ten to fifty feet; the hills just mentioned project very slightly from that level, though there are considerable hills, measured from the present river valleys. Between Oude Post and Uitvlugt there is a level plain, which marks the water-parting between the Kammanassie River and the Naugas River, a tributary of the Olifant's River West of this a small hill of Table Mountain Sandstone divides the two river systems, and a succession of small folds of that sandstone project through the Bokkeveld Beds, and give sufficient backbone to the slates to enable them to continue the watershed to the Kammanassie Mountain.

The Kammanassie Mountain is a double anticline carrying the closely-crinkled Table Mountain Sandstone high above the level of the country; when looking at a section of the mountain, especially on the north side, one can realise the nature of the sandstone that lies buried under the Bokkeveld Beds, and which crops out repeatedly in the long narrow strips. As a rule, however, the small folds in the Kammanassie Mountain are not drawn out, but exist as simple knee-bends, often with their limbs meeting at right angles. The range is an inlier of sandstone and quartzite, some thirty miles long, ending on the west at Dysseldorp, near Oudtshoorn.

In between this encircling hedge of mountains there is the basin of the Upper Olifant's River, lying at an average elevation of 2,000 feet above sea-level, while the hills scattered throughout the basin and whose summits do not rise above the plateau out of which they have been cut, never much exceed 3,000 feet.

The rocks in this basin are Enon Conglomerate and Bokkeveld Beds, the former lying in isolated basins in the latter. The Bokkeveld Beds consist of the usual clay-slates, shales, and one dominant sandstone band; they naturally take the mould of all the folds that are found on the Table Mountain Sandstone beneath them, yet they do not lend themselves to such close and repeated folding, bending rather on a larger scale; for this reason the hills in the area under discussion show large wavy anticlines and synclines, and the same bed becomes repeated by the whole mass of the slates and sandstones being doubled upon itself.

In among the slates there are two broad whale-back anticlines of Table Mountain Sandstone rising to the surface; the simile is strengthened when the mounds are looked at from a high point, for round the Table Mountain Sandstone the Bokkeveld Beds dip away with scarped faces looking inwards, thus to some extent resembling the waves on the surface when a whale's back does bob out of the water in actual experience. One of these rounded anticlines lies to the east of the road from Uniondale Road to the village. It never rose above the high-level plateau, so that the early denudation did not affect it, and it is now being exposed for the first time. The summit of the anticline forms the watershed for a number of small streams, and erosion is consequently very small, so that the shales have not been entirely stripped from the surface of the sandstone; indeed, by going over the surface one would never imagine that one was on Table Mountain Sandstone, except for the great quantity of Gwarrie bush that grows upon it. There is, however, a stream flowing north that has cut a deep channel in the sandstone, and in which the strata here are shown to lie nearly flat, with some wavy broad anticlines and synclines; before leaving the sandstone the water pours over a krantz into an immensely deep round pool it has dug for itself in the hard quartzite, and is thence taken out in a furrow to the farmlands on Keur Fontein. To the east of this whale-back there is a wide river-valley, on the east of which, again, and opposite the last whale-back, there is another one, but not so large. Some good fossils, asterids, gastropods, and lamellibranchs occur on the north of this outcrop of Table Mountain Sandstone, in a hard calcareous shaly sandstone which corresponds in position to the Fossiliferous Sandstone of the country further west. The Lange Vley River which flows between the two whale-backs escapes to the north-east from the plain through a poort in white sandstone, probably the Second Sandstone. The rest of the Bokkeveld area does not call for special mention; the rocks are clay-slates and shales, and calcareous sandstones weathering red, and are repeated by folding, producing long ridges of scarped hills, with sandstone on the top protecting them; at the junction of the Table Mountain Sandstone, the two Series are often closely folded together, as in the Kammanassie valley, Fig. 6. Fossils are very scarce, and the only place where I found them, besides that just mentioned on Woetjes Kloof North, was between Moeras Fontein and Roode Klip, east of Georgida. All the time I was working in the district there was a very severe drought, so that the only vegetation that the Bokkeveld hills carried was the hardy *Portulacarias*, the Kerrkei and Spek-boom, with Aloes, Cotyledons, and Gwarrie Bush.

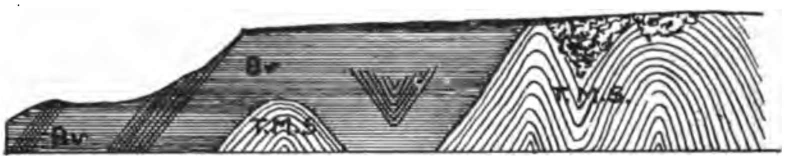

FIG. 6.—Section in Kloof above Moeras Fontein showing the folded junction of the Table Mountain Sandstone (T.M.S.) and the Bokkeveld Beds (Bv.). The cross lines in the Bokkeveld Beds represent sandstone beds.

The Enon Conglomerate lies in four basins, two large and two small ones. They were once continuous, but have been cut off by movements in the earth's crust, which has had the effect of raising and lowering the ground in a succession of broad waves, whose long axes lay north and south; then when the base-levelling commenced, the Enon Conglomerate, which was slightly humped up in certain places, was removed, and the underlying Bokkeveld Beds were exposed. In this way the Vlakte Plaats basin of Enon Beds is nearly cut off from the main basin of Oudtshoorn by the north and south fold, which brings up the Table Mountain Sandstone through the Bokkeveld Beds, a very narrow connecting bridge of conglomerate being left at Doorn Kraal. From the last place to Paarde Kloof the basin extends some twenty-five miles; there is a hump of Bokkeveld slates separating this basin from the next, which begins at Paarde Kloof and goes as far as Georgida, making a basin 16 miles long by 3½ miles broad. The other two are quite small, one two miles and the other only one mile in longest diameter and about a third as broad; they occur to the south and east of Wanhoop, high up on the watershed. We have two phenomena to explain in these Enon basins, firstly, how it is that what was once a continuous exposure of Enon Conglomerate became separated into isolated patches; and secondly, how it is that the base of the Enon Conglomerate varies from 3,000 feet elevation above sea-level at Wanhoop to less than 1,000 feet at Oudtshoorn. The first I have just tried to explain, and we shall see further evidence for my view in the section dealing with Baviaan's Kloof; for the second point there are two possible solutions; either the original valley in which the Enon Conglomerate was deposited was identical with the course of the Olifant's River from Wanhoop to Oudtshoorn, and the grading of the river bottom was the same, or what I think is more probably the case, the conglomerate has been carried down by a fold or fault, which increases in throw to the west. I think the second solution is the true explanation, from the following considerations:—A great deal of movement has gone on since the deposition of the Enon Conglomerate, for there are dips in that formation of 45° and 60°, as at Paarde Kloof; it is true that these were produced during the time that the northerly or north-easterly folds took place, but still they indicate that vast crust movements have taken place, and that the area has not been in stable equilibrium. Then again at Paarde Kloof, the Table Mountain Sandstone dips at 60° to 75° south, with the tops of the slopes truncated by a ledge cut in the mountain side, and against the dip-slopes the Enon Conglomerate is piled; on the ledge there are two small unmistakable patches of Enon Conglomerate. How are we to regard these? They cannot be extensions of the conglomerate as it now exists, for the beds in it dip steeply to the south-west; the only satisfactory way of looking at these is as having been originally laid down at this level, and thus indicating the level at which the whole of the Enon Conglomerate was originally laid down; the main mass of conglomerate which nearly touches them, but whose base goes down a thousand and more feet below them, must, therefore, have got into that position by earth movements. These two little patches of Enon Conglomerate on the Table Mountain Sandstones at Paarde Kloof are on a level with those at Wanhoop, and the base on which they lie is that on which, in all probability, the Enon Conglomerate of this intramountainous tract was laid down. A little later there is further proof of this faulting in the Vlakte Plaats section (p. 113). In Baviaan's Kloof there is even better evidence of this post-Uitenhage movement, and it is now almost certain that the movement affected all the patches of Uitenhage Beds in the Colony; perhaps also the Cretaceous rocks of Pondoland have got into their present position by the same set of earth movements. This will necessitate a certain amount of recasting of our ideas of the geology of the south-west part of the Colony; in a survey such as we are now making it is necessary to explain as many facts as possible by processes of Nature that we know are operating at the present day under ordinary circumstances, and to reject any thought of earth movements and faults unless backed up by very good evidence; there have been, however, many unexplained facts connected with the Uitenhage Beds, and especially the lowest member, the Enon Conglomerate, for instance, the closed basin to the east of Swellendam; and now we have unmistakable evidence of folds that carried down the Enon Conglomerate to anomalous positions, we can explain these occurrences by the reasonable assumption of faulting or folding, the more easily since considerable dips have been observed in these deposits.

The Uitenhage Beds in this district consist of three stages, the lowest is the Red Conglomerate, on this lies the White Conglomerate, and on top is a series of brown sands, red and blue marls, shales and claystones, possibly representative of the Wood Bed in the Uitenhage district. The top series is only present at a few places in the Uniondale Division, it occurs plentifully in Oudtshoorn; at Vlakte Plaats, on the boundary, there is a good exposure of it. The sands are frequently sufficiently compacted to afford a good building stone; but at Vlakte Plaats the stone seems too much impregnated with salts, which would effloresce were it used for walling, and cause flakes to scale off the dressed surface. To the north-west there is a great thickness of brown sands, greenish marls sometimes with purplish mottlings and grey shales like those of Heidelberg and Herbertsdale. I was unable, however, to find any plants in these, though I got a few indistinct plant stems from the sands in a quarry a little to the north of the Vlakte Plaats Railway Station. Further to the north-west there is an exposure showing the peculiar white clay-rock that occurs largely in the Uitenhage Beds north of Heidelberg.*

The best place for getting an idea of the relative position of the White and Red Conglomerates in the Vlakte Plaats basin is in the extreme east, on the hill on which stands the beacon between Paarde Kloof and Roode Krantz. Under one's feet there is the White Conglomerate dipping steeply to the south-east, and capped with recent gravel. The latter being derived from the conglomerate, resembles it very closely, except in the matter of dip, the remade gravel lying flat. To the east the Red Conglomerate dips under the White Conglomerate, and the upturned edge passes south-west across the Olifant's River at Roode Krantz, past Kookooboo, Kabooka, Rooi Heuvel, Rooi Poort, to Wolve Berg, south of Vlakte Plaats. All along this line hills of Red Enon Conglomerate rest on kopjes-veld made of Bokkeveld Beds, the escarpment facing south and the beds dipping from 25° to 45° in towards the basin; the dip-slopes pass in the interior of the basin under the scarped faces of the White Conglomerate that stretches from the Paarde Kloof beacon westwards to Jager's River and Wilge Boom, also on the south side of the Olifant's River. At the last-mentioned farm there is an excellent exposure of the White Conglomerate, which has in places a pillowy structure. On the surface of the Conglomerate one frequently finds the most perfectly polished quartz-pebbles, which must have been in that state before they were embedded. In the river-bed at Jager's River there are rocks containing thin chips of charred wood or lignite, like that which occurs lower down below Vlakte Plaats.* In the centre of the basin the Olifant's River has laid down wide alluvial flats, and one would expect the conglomerate on the south side to dip in to make a syncline with the beds just described on the south side, but all one finds under the mountains are detached hills with very variable dips, some southerly, but usually northerly. The northerly rim must have remained stationary while the southern rim was turned up, as the White and Red Conglomerates are at about the same level at present on either side of the centre, so that when the bending took place on the southern rim, the centre must have slid down. Taking a section at Vlakte Plaats, for instance, from Wolve Berg to the Water Kloof, one gets from the south, the following beds dipping 30° north:—Red Conglomerate; clays, sands, and White Conglomerate; red and blue marls; brown shales; white shales and clay rock; then a tract of country covered with soil, and on the north, piled against the Table Mountain Sandstone, Red Conglomerate, lying flat. The only way to explain this section is to suppose there is a fault between the topmost beds made of white clay rock and the bottom Red Conglomerate, the latter being held in its place probably by its attachment to the Table Mountain Sandstone slopes. It is a proof, I think, that the folding and faulting that took place south of the Cango Beds was already accomplished when the Enon Conglomerate was formed, and, indeed, the Cango Beds must have been exposed at that time, as the conglomerate in Oudtshoorn contains pebbles derived from these beds. The folding and faulting in the Enon Conglomerate, therefore, though closely following the old line, was long subsequent to the first series of folds. One sees additional evidence at the farm Loopende River, where the Red Conglomerate dips north and lies against the dip-slope of Table Mountain Sandstone. At Schoongezigt there is a sharp conglomerate or breccia, made of red bits of Table Mountain quartzite very brittle and splintery, lying in a mealy sand. The railway has opened a large ballast hole in the material. I am not sure whether this is crush-breccia of the Table Mountain Sandstone itself, or whether it is the Enon Conglomerate turned into a crush-breccia; it lies directly in the northern rim of the basin where the fault would run, and either explanation seems equally reasonable, but I am inclined to the second view.

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* Ann. Report, 1898 (p. 62).

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* See Reports by T. Bain and Dr. P. D. Hahn upon the alleged Discovery of Coal in the Division of Oudtshoorn. Cape Town, 1889.

The Georgida basin of Enon Conglomerate, which the railway cuts across near Tover Water's Poort, is more complexly folded than the last. In the centre there is a great mass of conglomerate hills, through which there is an anticline with an axis running west-north-west. Along the northern rim, the beds dip steeply south, differing greatly, therefore, from the Vlakte Plaats Basin. At Vaal Krantz they assume a most weird aspect, being overgrown with grey lichen. At Roode Kop there are quantities of swallow-tail crystals of Selenite; it is perhaps to the presence of gypsum throughout the Red Enon Conglomerate that the great fertility of the soil is due. To the north-west of Georgida homestead there is a certain amount of brown sands and sandstones under the Table Mountain Sandstone dip-slopes. The homestead stands on White Conglomerate, which down by the Olifant's River shows remarkable crushing in the pebbles; these, though made of the hardest, most brittle quartzite, have been crushed into one another, making cups of indentation; where the pebble has given, the fracture has been that of a plastic body like putty, and the separate bits of the pebble have remained in continuity. No heating or deposition of material from solution has occurred. The same thing is found in the Red Conglomerate at Nuy Siding, on the Worcester-Swellendam railway.*

The difficulty connected with this basin lies in the contact of the Enon Conglomerate with the Table Mountain Sandstone of Anthonie's Berg. The White Conglomerate lies piled against a cliff of sandstone behind Georgida homestead, and the question is, is this a fault-face, or is it a cliff of lateral erosion; the cliff is not an ordinary kloof-wall, because it stands facing a wide open plain. By lateral erosion, I mean the action of rivers, charged with a great quantity of gravel and boulders, cutting away a hill that obstructs their course, but on one side only; I have seen no evidence of such action in the Colony, where the rivers either cut straight downwards, or when they do cut sideways, they do so with gentle slopes on either side. Had there been evidence of glacial agency, this explanation would have been a very probable one, as such cliffs are known to have been eroded by glaciers,† but in the absence of any signs of such conditions having prevailed, though they well might have, it is best to invoke only the ordinary processes of erosion. There remains, then, the explanation that the cliff is a fault-face, and this view is strengthened when we find it strictly parallel to the anticline that runs through the centre of the basin from the farm Nooit Gedacht to Ronde Kop. Further along to the east, but outside the present area of the Enon Conglomerate, the junction of the Table Mountain Sandstone with the Bokkeveld Beds is a faulted one. This fault may be seen in many of the kloofs; one good section occurs above Zeekoegat (Moeras Fontein), where one also sees a magnificent exposure of coarse red recent gravel capping the high-level plateau ledge. A great part of the Georgida conglomerate basin is cut down and covered with red alluvium, derived from the disintegration of the gravels. The plain is steeply inclined, and it would be impossible to bring water on to it from the Olifant's River without pumping or bringing the water in a furrow from a great distance up the river; as it is, only the merest patch is irrigated just along the river, the thorn trees being cut down to make way for the fields; it is a pity to see the process going on, as the thorn trees stop the tearing away of the river banks, and help to keep the level of the river constant; when the trees are gone, the river will cut downwards more vigorously, and the side streamlets excavate "dongas" through the soil and gradually carry it away, so that eventually only bare rock will be left.

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* See photograph of one of the boulders in "An unrecognized agent in the Deformation of rocks." Trans. S.A. Phil. Soc., Vol. XIV. pt. 4, Cape Town, 1903.

† See Rogers and Schwarz, The Orange River Ground-Moraine. Trans. S.A. Phil. Soc. Vol. XI, 1900, fig. on p. 138.

The west basin is a deep hollow that has been cut out of the high level plateau, south of Wanhoop. The Enon Conglomerate was faulted down in among the Bokkeveld slates and Table Mountain Sandstone, the whole then was cut flat. After a time the streams coming from the south, that is, from the Kougha Mountains, in passing over this flat area, discovered the yielding conglomerate, and carried its substance away more rapidly than they could that of the older rocks, hence the basin now lies in a deep hollow and the rivers pass into the main valley by a deep poort.

The last basin of conglomerate on the Olifant's River lies nearly on the actual high-level plateau itself; it is in the form of a syncline of Red Conglomerate, and the bottom of the bend has been sunk but a small distance below the level of the plateau. If one travels a short way to the south, one suddenly comes to a tremendous precipice, the head of Baviaan's Kloof, and in the valley below, some 1,000 feet down, one again sees the Enon Conglomerate; the distance between the two areas, the one whose base is at least 1,000 feet above the other, is scarcely two miles. I shall first briefly discuss the Kammanassie River valley, and then turn to the Baviaan's Kloof.

VI. THE KAMMANASSIE RIVER AND WEST END OF THE LONG KLOOF.

Between the upper Olifant's River and the sea there is practically one continuous mass of Table Mountain Sandstone; it is folded throughout, sometimes so closely that both limbs dip south, while at others, more towards the sea, the strata draw out and rest in wide flat anticlines and synclines. The folds have raised the rock to a height which does not now exceed 6,000 feet above sea-level, and have sunk it to varying depths; vigorous erosion has gone on and cut deep valleys, which have been influenced by the folds, and the rivers run either parallel to the strata, the direction of least effort, or normal to it, the direction of greatest erosion. Sometimes the synclines have let down the Bokkeveld Beds to a position where they are now shown on the surface of the ground; the slates being more easily weathered than the hard sandstones and quartzites form valleys, but owing to the great scarcity of fossils, and, often, too, the absence of outcrops, one is at a loss whether to ascribe the rock underlying any particular valley to the Bokkeveld Series or to the great shale band that occurs near the top of the Table Mountain Series.

On the inner side of the Outeniqua and Kouga Mountains there are two main valleys of undoubted Bokkeveld Beds hedged in with Table Mountain Sandstone; the southern one is the Long Kloof, the other forms the Kammanassie valley. Between the two, in the west, there is a low ridge of Table Mountain Sandstone, or rather a succession of ridges, being the knuckles of anticlines appearing through the overlying shales. The strike of the ridge as a whole is a little north of east, but that of the various folds due east, the latter thus form tongue-like projections on the north side, the points where the anticlines pitch underground being directed towards the west. At Uniondale the strike of the outside edge of the whole ridge turns abruptly to the east-north-east, while that of the inner edge remains the same, hence the small hill that separates the Long Kloof from the Kammanassie valley west of Uniondale, on the east becomes wider and wider and higher and higher, forming the Kouga Mountains, the greatest mass of mountains in the Colony. On the north of the Kammanassie valley there is the mountain of that name running east and west, and the double anticline of which it is composed pitches underground north of Uniondale or opposite the angle of the change of strike in the other ridges of Table Mountain Sandstone. The north boundary of the Kammanassie valley is continued to the east along the new strike, at first by sandstone ridges that do not project above the high-level plateau. At Uitvlugt Berg they get a little higher, and at Oude Post Berg and Dwaas Berg they assume about the same proportions, between the true Oliphant's

River valley and the prolongation of the Kammanassie, as they do between the Kammanassie and the Long Kloof valleys west of Uniondale.

The extraordinary part of this Kammanassie valley is that although there is a continuous Bokkeveld valley between hills of Table Mountain Sandstone, as far as the farm Dwaas, the part beyond Uitvlugt, or the upper twelve miles, has been invaded by side streams from the Olifant's River and its waters captured: the Kammanassie River has been beheaded. The Long Kloof, on the other hand, never had a river of its own at all; its whole length is divided into small drainage areas that have been invaded by streams running north, south, east, or west. The Long Kloof commences to the east of the farm Doorn River on the George-Oudtshoorn road. For the first thirty-five miles the rivers that traverse it run straight across it to the Kammanassie valley, and take no notice at all of the difference in hardness between the Table Mountain Sandstone and the Bokkeveld slates; only at Ezeljagt and Molen River do the streams run even for a short way along the strike of the valley. From Molen River eastwards the valley-form of the Long Kloof is more pronounced; there is a succession of streams, some running east, others running west, each forming a separate valley with a low nek between it and its neighbours on either side. Molen and Diep Rivers drain into the Kammanassie; east of these the Gwarina, running west to join the Diep River, has been drained away through the mountains, and the water now flows straight to the sea by the Keurboom's River; Wolve Kraal and Avontuur again, drain into the Kammanassie, while beyond there is a long river valley running east, but it also soon leaves the Long Kloof and turns northwards through the Kouga Mountains to join the Baviaan's Kloof River.

The reason for this anomalous drainage lies in the fact that in bygone times there was an old land-surface formed by a plain of erosion, that is to say, the rivers were obstructed or stopped in their course, and instead of cutting downwards, had reached bottom, and were constrained to meander from side to side, reducing all the inequalities in their course to a more or less level flat. When the obstruction of the rivers was put an end to, probably by the rising of the land, the river-systems had different erosive values, some being more vigorous than others; and whereas in ordinary circumstances the encroachment of one river on another is a very slow process, in the district in question, owing to the stagnant and undecided courses that the rivers had on this high level plateau, a very small difference in fall was enough to turn the waters from one river-system into another.

The head of the Kammanassie ends in a cul-de-sac in the high-level plateau; all round there is the level, gravel-capped plain and a number of deep ravines penetrate into it. The heads of the gullies have no springs in them, nor can we get any reasonable explanation as to how they were formed until we find that the effective head of the Kammanassie River now lies in the Long Kloof, actually on the summit of the Prince Albert Pass. The river, therefore, erodes its valley faster than it could without these waters which have been stolen from another river-system; erosion working up-stream owing to the increased fall, the undertow excavates these dry ravines and makes them deep-bottomed from their commencement.

The rest of the Kammanassie valley is practically a V-shaped gorge cut in the high-level plateau, the difference in height between the river and the top of the plateau is about 800 feet at Uniondale, and increases to 1,000 feet further down. The sides are extremely abrupt.

On the plateau, owing to the drainage that such deep gorges effect, there is very little water, and there are therefore few farms; yet where there is an anticline of Table Mountain Sandstone which acts like a dyke in stopping underground water so that springs come to the surface, as at Vogelstruis Fontein, the ground is found suitable for cultivation. The main difficulties are that the gravel is often coarse and cemented with iron, and very thin soil collects on such a foundation; the flats, too, being high and exposed are swept by the full force of the wind. In the gorge itself there are rich strips of alluvium along the river, but owing to the extreme narrowness of the whole valley these patches are very small. It used to be necessary to first climb out of the valley to get a road to the village, and then go along over the high plateau; as the cliffs are so exceedingly steep, this was always a matter of difficulty, but a road is now being cut along the sides of the hills nearly on a level with the various farms.

On the north side of the valley near the west end, there is a great difficulty in arriving at an idea of where the Bokkeveld slates end and the Table Mountain Sandstone begins, owing to the fact that the two formations are so intimately folded together and the whole planed down to a definite level, which is covered with a thick capping of gravel: to complicate matters there is the shale band near the top of the sandstone. It thus happens that in among the mountains of Table Mountain Sandstone one finds little fertile valleys with slate bottoms, where families of Boers have settled and lived shut out from the world for a very long time. Looking over the country from the top of the mountains, for instance, by Eland's Fontein and Diep River, one would fancy the whole place unoccupied, whereas there are a great number of houses tucked away in the deep ravines. The same is the case at the other end of the berg on Van Jaarsveld's Aanleg, where there is a strip of the shale band, and further in the mountains there is a patch of corn-land on a tongue of Bokkeveld slates that is folded in with the Table Mountain Sandstone.

Examples of valleys formed by the Shale Band are very frequent in the Long Kloof, but only the head of the kloof has up to the present time been geologically surveyed, and it is hard to form a correct judgment without the whole evidence at hand.

The old main road from the Long Kloof to the Knysna lakes passes over a mountain called Duivel's Kop: the road winds up the soft-beds of the Shale Band, and from the top of the pass one can follow its course in the valley below, where the strata are lying at low angles. Wherever the Shale Band comes to the surface the ground is more thickly covered with bushes owing to the more porous and water-holding character of the rock, and there is a sprinkling of the Karroo plants, such as cotyledons and aloes, due to the soil having a less acid reaction than that on the sandstone of the Table Mountain Series. Eastwards the whole band passes round Schoonberg down a long narrow valley parallel to the Long Kloof, and at Molen River, three such narrow valleys can be counted, which are doubtless due to the weathering of the Shale Band. The term Shale Band has been used so as to draw attention to the fact that it is the same that has been described from Ceres, Clanwilliam, etc.; but even in the first mentioned locality it is very changeable, now seen as a great thickness of shale and slate, as at Gydow Pass, now as a Glacial Conglomerate, as at Pakhuis Pass,* and still again as a porous sandstone, as in Mitchell's Pass; it is in this last condition that we find it on Duivel's Kop Pass.

VII. BAVIAAN'S KLOOF.

The most important part of the district under description, from a geological point of view, is the Baviaan's Kloof. Two months were spent in it, and a much longer time might have been profitably employed there had there been an adequate map on which to put down details, and had it not been for the bitter drought, which rendered it difficult to get provisions and transport.

Baviaan's Kloof is a continuation of the Kammanassie and Olifant's River Valleys eastwards. Between the two last mentioned there is the Kammanassie Mountains, while in the Baviaan's Kloof there is the single pair of boundary mountains; these, however, are the same for both river-systems—the westerly flowing one and the easterly. The distance between the head of the kloof and the point where it joins the Kouga River is, in a straight line, 50 miles, the distance between the crests of the enclosing mountains varies from nine to twelve miles. The kloof consists of two parts: a wide open, bevelled plateau, reaching high up the sides of the mountains and forming an extensive plain in the middle, all covered with sand and gravel; and a number of fold-basins, which have let down the Enon Conglomerate to a depth of over 1,000 feet. There are four fold-basins, but two more lie caught in the hollows of the complicated folds that go to form the larger basins. The general plan of the basin is a fault on the north and a steep slope on the south, with semi-circular folds at each end (see Figs. 7 and 9), but the type is only fully realised in the first or westernmost of the four large ones. The sizes of the basins are respectively in miles: 7·4 by 1·4; 10·5 by 1·5; 19·7 by 3·1; and 6·3 by 1·4; they lie sunk at a thousand to twelve hundred feet below the plateau; they are connected by immensely steep valleys of erosion through the Table Mountain Sandstone. In a sense, too, the basins themselves are valleys of erosion, as there is every reason to believe that the Enon Conglomerate at one time filled them entirely up to at least the level of the high plateau level, and that that rock was cut flat with the rest of the formations.

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* A. W. Rogers, a Glacial Conglomerate in the Table Mountain Sandstone, Trans. S.A. Phil. Soc., 1902, Vol. XI.

South of these basins and under the crests of the Kouga mountains, there is a second valley, which has not yet been very much eroded. The kloofs from the Kouga Mountains pass straight across it to Baviaan's Kloof River, and the valley-form is only shewn as a succession of depressions in shale rock. The folding is so intense that one can explain the occurrence of shale in among the Table Mountain Sandstone either as being the Shale Band of the series or the Bokkeveld Beds. Remembering that the Table Mountain Series Shale Band, in the nearest available exposure at Duivel's Kop was soft sandstone with no argillaceous beds, one is inclined to regard the rock in Baviaan's Kloof as true Bokkeveld, but to get this one has to suppose some rather extensive horizontal thrusts, but still, as I have already pointed out, the argument from the nature of the rock is rendered invalid by the many varieties one finds within a short distance of each other in Ceres.

The first basin includes the two farms Nieuwe Kloof and Riet River, sometimes called Vlakte Plaats. On the north is Vaal Water, Adam's Kraal and some unsurveyed Government ground; on the south there are the farms Quagga's Vlakte, Bosch Kloof and Matjes Fontein, with again some unsurveyed ground between these and the crest of the mountains. At Nieuwe Kloof there is the one road by which you enter the Kloof; there is no way of getting out of it again unless one goes right through to the other end and on to Humansdorp. Oude Berg lies at the western end, but in the drainage area of the Olifant's River; the old road that here zig-zagged up the fault-face has long been abandoned, and the new road passes down the second of the great lateral ravines on the north side. The first lateral ravine is a cul-de-sac, a flat-bottomed cañon eaten out of the Table Mountain Sandstone; the rocks are vertical and strike diagonally across the ravine. A dry waterfall is situated at the head, and the amount of water that flows over is very small; there is no evidence of the ravine being one of erosion, it is rather a structural rift rounded off by erosion. On the south side of the basin there are several deep kloofs coming north from the crests of the mountains; they cut very deeply into the plateau that is here perfectly normal. The first of them leading to Quagga Vlakte is entirely untraversable, owing to the perpendicular walls and immense square blocks of sandstone that choke up the bottom. Near the mouth, where it opens on to the plain of the first basin, there is a dip-slope of Table Mountain Sandstone crumpled into close folds. By going up the Oude Berg one can get on top of the plateau and walk along the edge of the cañon and examine the walls. Presently the depth rapidly decreases, and there is a wide open flat underlain by slate; this is the western end of the slate band that runs east and west under the crests of the mountains; to the west there is the farm Zand Kraal in a transverse valley, that looks like the continuation of the slate band, but I was unable to find anything but sandstone in the valley. To the east the Quagga Vlakte shales develop into the great transverse valley of Bosch Kloof, Matjes Fontein, Gonpha and Numah, which I shall presently describe. The amount of water flowing down the Quagga Vlakte River is practically nothing: there are a few small leaks from the joints in the sandstone, which after rain are sufficient to fill in the pot-holes and hollows in the stream-bed, and also to fill a deep hole under one of the waterfalls which lies squeezed in between a perpendicular, or even overhanging cliff, on one side, and a nearly perpendicular cliff on the other. We have then at the very head of Baviaan's Kloof two lateral stream-beds opening on to a fully-formed wide valley at right angles. The southern side of the main valley, as just mentioned is a dip-slope of Table Mountain Sandstone, the north is a vertical fault-face; the distance between the two is three-quarters of a mile, widening considerably to the east; on the west, the fault from the north face is continued in a semicircle and abuts squarely on the dip-slope: on the inner side of the semi-circular portion there is a small strip of sandstone strata faulted off from the main body yet dipping underground normal to the circular fault, that is to say, there is both a semicircular dip and a semi-circular fault at the west end of the first basin. On the east end we shall see there is a similar feature, but here it is the south dip-slope that turns round and abuts squarely on the north fault-face, Fig 7.

The northern fault-face runs a little north of east, but is interrupted in the centre by two bulges or blocks of Table Mountain Sandstone that have remained in their places when the rest sank. The western of the two is a block of brecciated sandstone, in which the beds are still recognisable, and are lying flat; the top of the block is on a level with the high-level plateau. The eastern of the two is much less conspicuous, and were it not for the road from Nieuwe Kloof to Riet River going over it, it might be overlooked among the Enon Conglomerates: the substance of the rock is minutely and completely brecciated, so that the whole closely resembles the White Conglomerate that rests on it; the outcrop is perhaps a quarter of a square mile, but this naturally gives no idea of the entire amount of material that has been treated in this way. To the east of this last there is a small kopje of grey shale, evidently belonging to the Bokkeveld Series. To the east of this again the fault-face is precipitous.

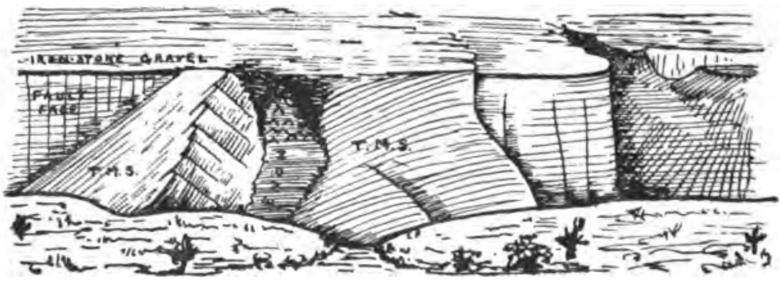
IRONSTONE GRAVEL
FAULT FACE
T.M.S.
T.M.S.

FIG. 7.—View across the Baviaan's Kloof River at the end of a fold-basin just east of Riet River, showing the dip-slopes abutting on the northern fault-face. A small patch of Red Enon Conglomerate has got in behind the uppermost dip-slopes of the Table Mountain Sandstone. The high-level plateau is also shown.

The folded rim on the south is a dip-slope thrown into complicated twists and bends; the line of bare rock-faces runs due east to the farm house on Riet River and then sweeps round in a wide curve towards the north, meeting the fault-face at an acute angle (Fig. 7). The fault rapidly dies out to the east and the sandstones on either side come together. Behind the dip-slope near the fault-face, and where the strike is north and south, there is an escarpment with a small lenticular patch of Red Enon Conglomerate lying at the foot, and resting on the dip-slopes that dip under those that bound the basin. The Baviaan's Kloof River has cut a poort through these dip-slopes near Riet Fontein homestead, and winds about in a very deep Kloof all in the Table Mountain Sandstone, till it emerges again in the open at Verloren River.

The whole of this basin is filled in with Enon Conglomerate, partly of the red variety, partly of the white, with a small portion of the sandy brown kind. Opposite Nieuwe Kloof as one enters the broad flat at the bottom of the basin, one sees to the south an immense ribbed hill of dull red conglomerate dipping towards one, that is, to the north, and at the same angle as the Table Mountain Series does; in fact, the two seem perfectly conformable. The Red Conglomerate in turn dips under the White Conglomerate. A little to the east there are some considerable kopjes resting on the Table Mountain Sandstone crush-breccia, composed in their lower part of White Conglomerate weathering into the usual bee-hive forms, and on top, of brown sands with spherical iron concretions about the size of a pea. The sands on top of the high level plateau occasionally take on exactly the same peculiar structure, which makes the rock look like a true pisolite; it is, however, a manner of weathering, the iron in solution is deposited in these spherical blobs, and the uncemented sand gets blown away or drops out, leaving the spherical bodies freely protruding from the surface. The rest of the valley is underlain by Uitenhage Beds of some description, but very little is exposed, the rich red sandy soil covering everything. How deep these Enon Beds go down it is impossible to say, and it would be exceedingly interesting to know, for once that were understood, the whole fall of the east and west fault could be gauged.

Besides the Quagga Vlakte kloof, there are two more that enter the basin by the southern border. The first leads up the Bosch Kloof, and bifurcates into two main branches in the midst of the sandstone krantzes. The Table Mountain Sandstone is at first crumpled; further up the kloof there is a syncline bringing in a narrow strip of Bokkeveld slates, then a large anticline, with the two limbs meeting at an acute angle. On the south face of this, the beds exhibit their bare dip-slopes, and it looks almost as if there had been here an abortive attempt to let down the superincumbent beds to form another fold-valley similar to the Nieuwe Kloof and Riet River one. Further south the folding does bring down the Bokkeveld Beds to a level with the river, but the folding belongs to the time of the general mountain-building.

The Bokkeveld slates are exposed in the very deep kloofs that the rivers have cut across the strike of the rock, and the two main streams on the farm Bosch Kloof are separated by two very steep neks of slate; this farm is separated from the next, Matjes Fontein, in precisely the same way. Right in the middle of the slate outcrop there is a very massive block of Table Mountain Sandstone, resting horizontally on the centre of the syncline. How came it there? It may be that the slates are only the Shale Band in the Table Mountain Sandstone enormously developed, but I am inclined to believe that the slates belong really to the Bokkeveld Beds, and that the horizontal sandstone has got into its place by an overthrust. There is evidence of a certain amount of overthrusting at the junction of the slates with the sandstone mass of the Kouga Mountains in the western of the two kloofs on Bosch Kloof, but it leaves one with no definite idea as to how the great overthrust took place. It is in this western kloof, right in the Table Mountain Sandstone, that a few of the great Sepree trees (*Widdringtonia cupressoides*) still remain.

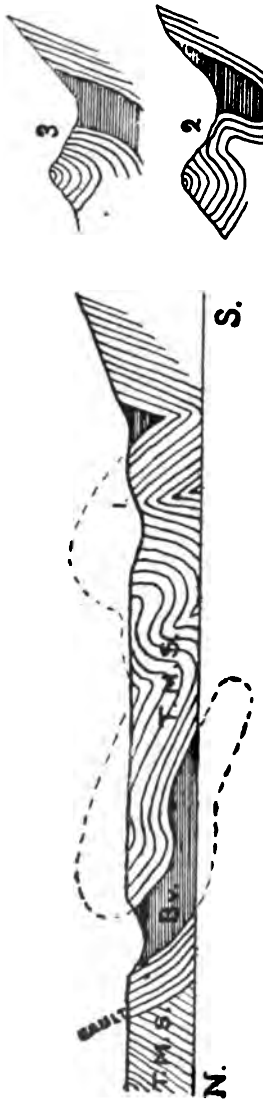

FIG. 8.—Section on east bank of Matjes Fontein Kloof, showing the folds in the Table Mountain Sandstone (T.M.S.) and the manner in which it is thrust over the Bokkeveld Beds (Bv.). 1, 2, and 3, represent the nature of the anticline as it is followed east towards Gonpha, and the progressive development of an overthrust on this side also.

On Matjesfontein, in the same line, we get on the north dip-slopes of Table Mountain Sandstone passing under the slate; then a band of slate 1200 feet thick, dipping at a less angle, and, as one goes southwards, passing beneath the level of the river and making the slates disappear (Fig. 8). South of the house, again, we get an anticline of Table Mountain Sandstone, and then a V-shaped syncline, holding a narrow band of slates, this time undoubtedly of the Bokkeveld Series. Following this syncline with its slates eastwards, towards Numah, one finds the anticline disappearing and the band of slate no longer held in a trough, but dipping north under the mass of Table Mountain Sandstone, as if to meet the band that disappeared underground near the homestead on Matjes Fontein. As a matter of fact, I do not think the two bands do meet underground, but each is a separate syncline, separated by an anticline of Table Mountain Sandstone, the top of which has been depressed and flattened out, so that the beds appear to be horizontal. It is, however, a very difficult region to work in, owing to the tremendous kloofs, and one has to go over the ground three or four times in order to get even a working theory of the nature of the country. From Matjes Fontein there is a bridle path over the Kouga Mountains to a farm in the Long Kloof, a distance of twenty-five miles in a straight line between the two houses, and the whole of the distance is across the strike of chain after chain of mountains, separated by kloofs that leave narrow gashes 4000 ft. deep. The Kouga Mountains are the wildest bit of country in the Colony, and were the last stronghold of the Bushmen in these parts.

The next valley of the Baviaan's Kloof Series is irregular. It commences close to the first in a narrow band of Enon Conglomerate; the main river, however, instead of taking advantage of the loose gravel, has cut a channel for itself parallel to the fold-valley in the Table Mountain Sandstone. At the Kasey it touches the conglomerate, but leaves it again to burrow into the hard quartzite, and only comes into the open fold-valley near its centre. The second basin contains the farms Paarde Kloof, Kasey, Verloren River, Uitslag and a small part of Beako's Nek; on the north there are the flat plains of the high level plateau going up to the crest of the Baviaan's Kloof Mountains, most of it Government ground, and in the south there are the cattle farms Verlaten River, Gonpha and Numah, the rest of Beako's Nek and Vley Kloof.

Beginning at the Paarde Kloof, the Enon Conglomerate commences abruptly on the edge of a precipice cut by a stream running south from the Baviaan's Kloof Mountains: the rock, white conglomerate, shows a gentle anticline, and its southern side is cut into a knife-edge of this brilliantly white rock which separates the valley of the main river from that of Paarde Kloof. The rock exposed on vertical faces weathers in all the peculiar fantastic shapes characteristic of the conglomerate. There is an odd little hill of Bokkeveld slates and sandstone opposite the homestead which has not slid down along the fault-face so much as the rest of the ground. The fault begins suddenly on the east side of the deep kloof west of Paarde Kloof. On the west wall there is no indication of any displacement: from the commencement the fault runs a little south of east with the Enon Conglomerate attached. The latter is mostly of the red variety away from Paarde Kloof, and weathers in the extraordinary bee-hive forms. Close to the farm houses on Verloren River, and along the course of the disused road, one can see the Table Mountain Sandstone under the Enon Conglomerate (Fig. 9), so that the throw of the fault is not so great as in the first basin. At the homestead the valley widens out, the fault-face turning due east, while the dip-slopes on the south side sweep round in a curve as in the first basin, and abut abruptly against the fault-face opposite the homestead on

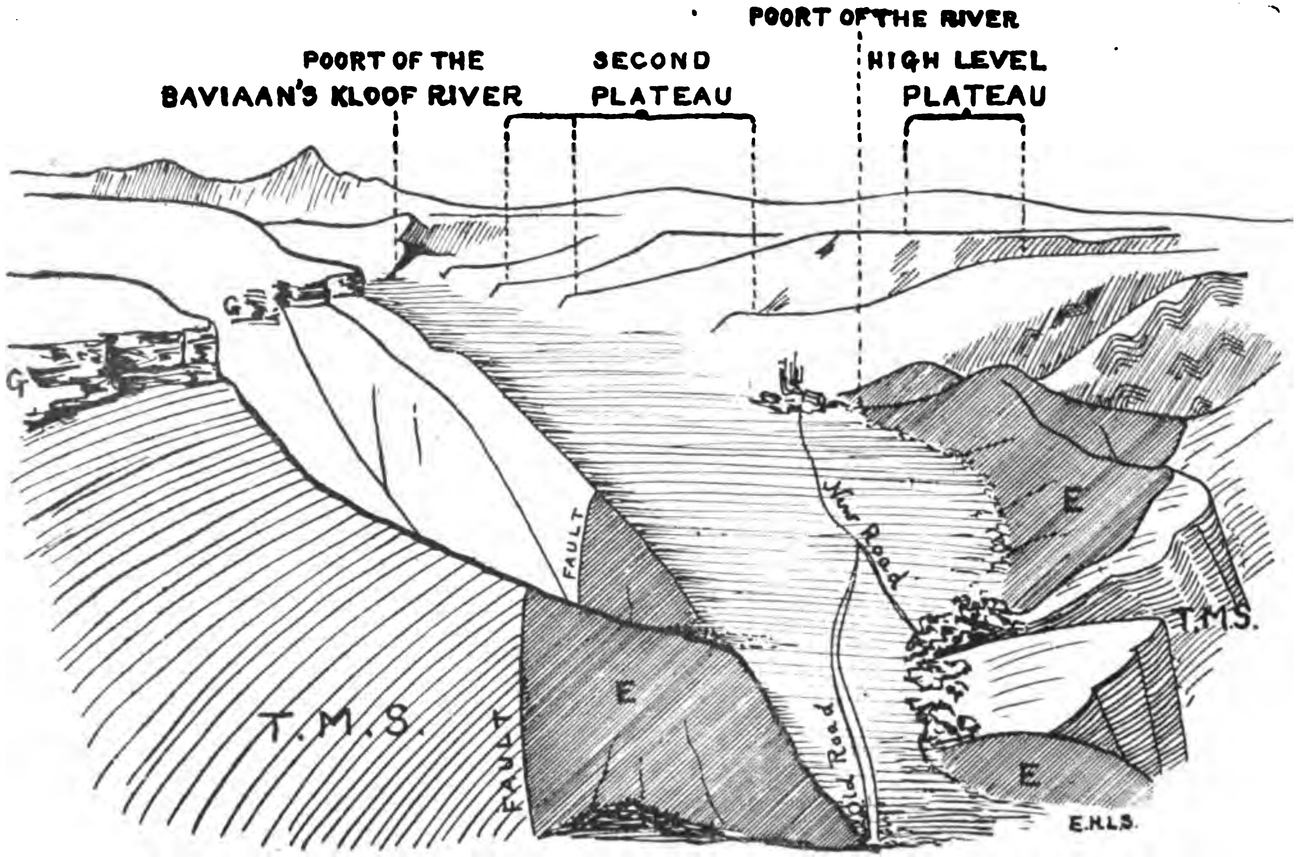

FIG. 9.—Baviaan's Kloof ; the second fold-basin showing the homestead on Verloren River. The Red Enon Conglomerate (E) is shown resting on dip-slopes of Table Mountain Sandstone (T.M.S.) on the south, and faulted against the sandstone on the north. The krantze of ironstone gravel capping the plateau are seen on the left, the Baviaan's Kloof Mountains in the distance.

Beako's Nek. It is not at all easy to make out the nature of the fault-face east of the widening of the valley; there has been perhaps some lateral shear, brecciating the rock, and obscuring the bedding. First of all there is a certain amount of folding that evidently belongs to the mountain-building period; then the faulting or steep folding, letting down the bottoms of these basins, and then lateral shear, tending to distort the east and west sinking of the strata. Towards the eastern end of the basin there are two faults, each producing a valley, the northern one very much smaller than the main one. Taking a section (Figs. 10 and 11) to the west of Beako's Nek homestead straight across the valleys we get, starting from the south:—Dip-slopes of Table Mountain Sandstone truncated on top by the high-level plateau: on these rest Bokkeveld Beds with nests of *Terebratula (Cryptonella) baini*: then flat ground covered with soil, ending on the north with a steep hill of Table Mountain Sandstone dipping north at 45°, and showing the edges of the strata on the vertical face: dip-slopes of Table Mountain Sandstone, with perhaps a little shale at the bottom of the valley, but it is hard to recognise, as the ground is covered with debris, yet the "harde veld" vegetation seems to indicate more than mere sandstone subsoil: on the north of this again come dip-slopes of Table Mountain Sandstone dipping 75° south, and truncated on top by the northern continuation of the high-level plateau. A mile further east all signs of both valleys die out, and there is simply a continuous section of Table Mountain Sandstone cut to the high-level plateau and indented only by the V-shaped gorge of erosion in which the Baviaan's Kloof River runs.

These two sections illustrate the sudden way in which the basins end, but there is a difficulty in explaining how the Bokkeveld Beds get pinched out. The slates can be certainly recognised by a bed of calcareous sandstone corresponding to the Fossiliferous Sandstone, which is full of Terebratulas, and occasionally the cast of a *Leptocoelia flabellites*; they lie on the dip-slopes of sandstone, and then can be followed in a ridge (see Bv. in Fig. 10), which makes straight for the nearly vertical face of Table Mountain Sandstone that ends the basin in the east. Above the place where the slates apparently enter the sandstone there is a continuous exposure of Table Mountain Sandstone which dips throughout at a constant angle to the north, and one is, therefore, driven to the conclusion that the Bokkeveld Beds are actually enwrapped by the sandstone (Fig. 11).

The course of the main river on the east of the basin is unusual; it leaves the open flats of Bokkeveld Beds and gets in behind the dip-slopes of Table Mountain Sandstone, cutting a very deep gorge with nearly vertical sides, and then touches the open valley again before plunging into the cañon that leads

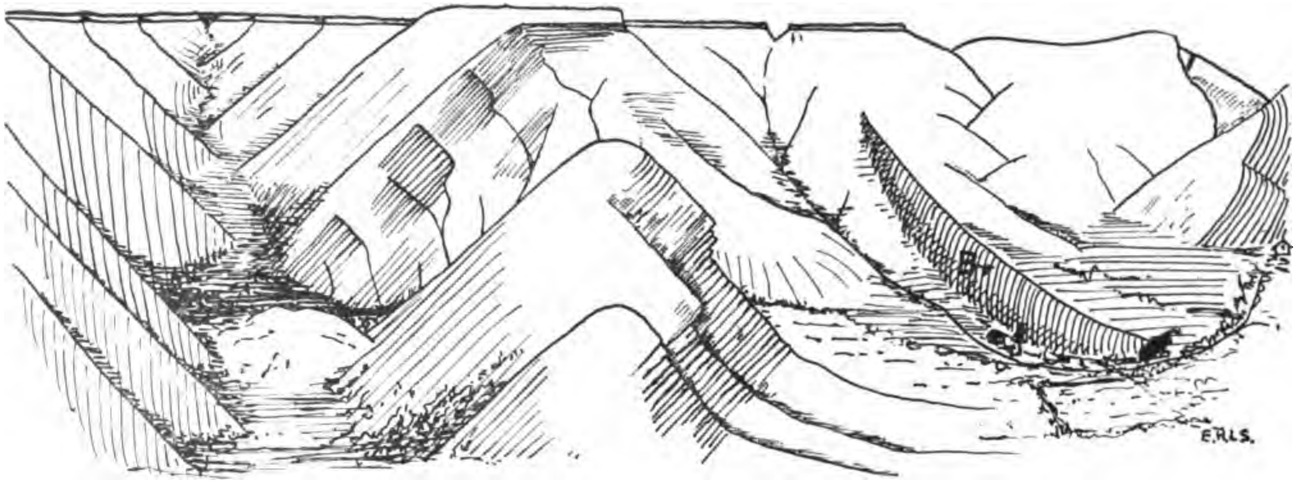

FIG. 10.—Showing the two homesteads on Beako's Nek. Bv. is a ridge of Bokkeveld Beds. The two fold-valleys and the gravel-capped plateau are well shown.

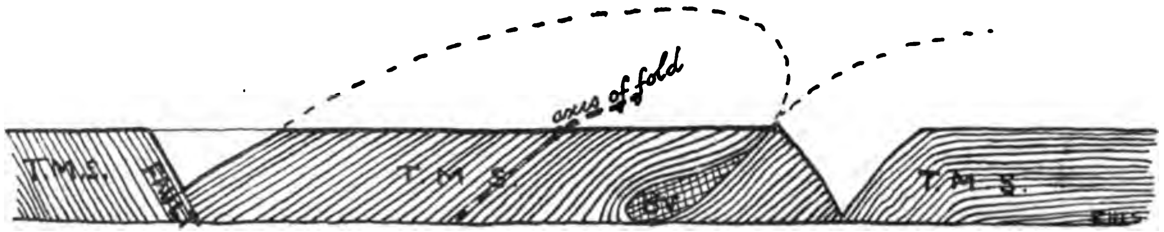

FIG. 11.—Section through Beako's Nek to show how the Bokkeveld Beds (Bv.) are enwrapped by the Table Mountain Sandstone (T.M.S.).

to the next basin. In the narrow strip of rock between the open basin and the course of the river to the west of Beako's Nek homestead, there is a trough-fault which has let down a wedge-shaped mass of sandstone along the dip.

In the gorge opposite the trough-fault there is a ledge some 150 feet above the river-level, it is covered with large rounded boulders of white quartzite, and is undoubtedly an old river terrace. All along the south side of the open basin, from Verloren River, there are plateaus cut to one level and similarly covered with river gravel, thus showing that there existed in some not very remote times a stoppage in the river which made the river cut these flat plateaus, just as in far more remote times the high-level plateau was formed, and also as at the present day, the floors of the fold-basins are being cut level. Similar remains of a low-level plateau exist in the next basin.

Turning now to the high-level plateau, one has to mount the 1000 feet that separate it from the farm houses, and at most places one finds a dead flat covered with iron-cemented gravel, and deeply cut into by a labyrinth of kloofs that carry the streams from the mountains. At Beako's Nek, however, the level is broken, and there are low hills rising from the old plain. The upland plateau was originally fine grazing ground, but owing to the unfortunate custom of burning the veld, the ground is now of very little use, as the hardier and worthless bushes have been given the advantage of the more useful plants; one farmer, however, recognising the evil, has kept down the veld-fires as much as possible, and his ground is gradually recovering. The difficulty on these high flats is the want of water: a little exists in the bottoms of the kloofs, but usually the sides are so precipitous that cattle cannot get down to drink, and many perish annually by falling over the krantzes. If one goes southward towards the crests of the Kouga Mountains, the kloofs break up into a number of branches till from the actual summit of the range the small watercourses come off at nearly regular intervals. The plateau form is continued high up as a bevel, and each of the small streams cuts deeply into the levelled surface, the rocks, hard quartzites and sandstones, which nearer the centre of the basin lie nearly horizontal, except where disturbed to form the fold-basins, dip more nearly vertically near the crest of the range. In this way one gets an extraordinary effect: each rock stratum is cut into an arch with long vertical limbs and a top semi-circular section; these are placed like a pack of cards, vertically, and long rows of these all standing at right angles to the lines of peaks make a very peculiar sight. So narrow is the ground between the kloofs that one is obliged to walk in the centre, as the ground slopes away so rapidly on either side, and then goes vertically down to the bottom of the stream-bed. It is very remarkable that with so suitable a gathering ground for rain water the side kloofs have no running streams in them except after rains. This is due I think to the complete extinction of all bush and forest that once covered those mountains: in only two places, in extremely difficult ground, right in the very centre of the Kouga Mountains, did I see small patches of the original forest, all else has been destroyed by the systematic burning of the veld.

At the crest of the range one looks over into the Long Kloof, but between that valley and Baviaan's Kloof there are two more ranges of what I might call first-class importance, and several smaller ones, each being separated by very deep kloofs. The kloof immediately south of the first range of peaks on the Kouga Mountains is cut in the axis of an open anticline: that is to say, open in the sense that the two limbs are not closely pressed together as they are on the north of the line of peaks. I believe there ought to be a shale band or even a narrow band of Bokkeveld Beds somewhere to the north of the first (most northern) crest of the range, as on either side of the sections of the kloofs the shales do come out, but I could find no evidence on the surface on Vley Kloof or Beako's Nek, and with such intense folding as there is here it is quite possible that the slates have been squeezed out.

The third basin in Baviaan's Kloof is the largest, and is divided into two parts. The more open portion in the west includes Klip Fontein, Klein Poort and Rust-en-Vrede; the narrower eastern portion includes Joachim's Kraal, Zand Vlakte, Eenzaamheid and Mist Kraal. It is separated from the second basin by a diagonal strip of high country, cut to the level of the upland plateau, and traversed by the winding gorge of the river; it is about 2½ miles across. The eastern end of the second basin is formed by the border of the Table Mountain Sandstone outcrop curving from the south to meet the straight edge on the north; the western end of the third basin is formed by the border of the Table Mountain Sandstone outcrop curving from the north to meet the straight edge on the south: the strip of Table Mountain Sandstone left standing between the two basins may therefore be explained as the resultant of the north and south folding combined with east and west one. In the centre of the basin, the north and south fold again comes into prominence, and by shifting the outcrop of the Table Mountain Sandstone a couple of miles to the north, narrows the basin to half its width.

The above explanation depends on the view that the basins represent the synclines, and the encircling high ground the anticlines, of very wide, north and south folds in conjunction with an east and west system, somewhat on the principle of a honeycomb towel.

The southern rim is the simpler, so it will be best to take it first. The outcrop of the sandstone boundary runs a little south of east, and there are dip-slopes of Table Mountain Sandstone, crumpled into knee-bends. On these rest the Bokkeveld Beds, which contain a great sandstone bed, which is probably the Second Sandstone of the earlier classification. The slate formation is naturally as folded as the underlying one, and the band of white quartzitic sandstone in the uniform blue shales reveals the fact more prominently than where this sandstone is absent. The Table Mountain Sandstone also may often be seen pushing up a knuckle into the slates, and nearly every kloof on the boundary shows such a fold, but these do not make any mark on the topography of the country.

The straight edge of the boundary continues through the farms Tchnugando and Tchando, names that perpetuate the memory of the Bushmen that once swarmed in these parts: the distance is twelve miles. Then there is a sudden shift of the outcrop two miles to the north, and the western face of the sandstone thus shifted exhibits a vertical face, in which the strata are lying nearly flat. The Bokkeveld ridges continue to the thrust-face as if to be swallowed up in the sandstone, but I think they must be cut off by the fault rather than become enwrapped as in Beako's Nek. The nature of the northern boundary of the Table Mountain Sandstone after the shift is precisely the same as that to the west of it, but the slip of Bokkeveld Beds that rests on the sandstone is very narrow, and soon gets covered entirely by Enon Conglomerate. After a further course of twelve miles the dip-slope rounds off the basin at Mist Kraal by joining up with the dip-slope on the opposite, that is, the north side, of the basin.

The northern rim is complicated by the presence of an attempt to form a small parallel fold-valley as in the second basin and by an enormous bulk of brecciated quartzite.

Mounting the high plateau behind or north of the shop Studtis, on the western portion of the farm Klip Fontein, one has to go up a dip-slope of Table Mountain Sandstone, truncated on top by the plateau, just as on the southern rim of the basin. The dip-slope, however, becomes detached from the horizontal strata behind by a vertical fault, and tracing the dip-slope westwards the inclined beds will be seen to pitch underground, leaving the fault-face exposed. To the south of the dip-slope there is a hill of Bokkeveld slates dipping north, underlain by Table Mountain Sandstone, of which the scarped edges of the strata face the open valley. This strip, therefore, resolves itself into a V-shaped syncline between parallel faults (Fig. 12). The Bokkeveld Beds run in a narrow band westward and turn round to the south, parallel to the border of the Table Mountain Sandstone: the way they get pinched out is not apparent. On the east the slope of Table Mountain Sandstone pitches underground and the end of the Bokkeveld Beds gets covered with Enon Conglomerate. Opposite the homestead on lower Klip Fontein there are a few fossils in the grey shales, among others some *Rensselaerias.*

On the upper Klip Fontein, mid-way in the diagonal border of the western end of the basin between the Table Mountain Sandstone and the Bokkeveld Beds there issues a very strong spring through several "eyes," the place is covered with thick bush and tree-euphorbias, and the general nature of the place is similar to that of the spring at Uitenhage. Further to the east, at Rust-en-Vrede, another spring bursts out of the level flat in the very centre of the valley, and away from the river bed; the ground here is underlain by Enon Conglomerate with Bokkeveld Beds probably under that. To the south of the spring on Klip Fontein there is a bevel covered with red soil and densely covered with aloes 12 to 15 ft. high, the boles of which stand massed together, so that we can scarcely creep between. It is extraordinary to see the great deep kloofs that came north from the Kouga Mountains open on to this bevel without so much even as a definite stream bed, so seldom does water flow down them.

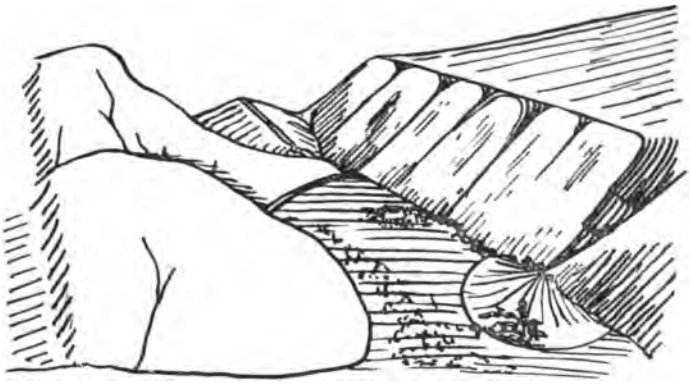

FIG. 12.—Lower Klipfontein, standing on an alluvial fan with Klein Poort in the distance. The sketch shows the bare dip-slopes of Table Mountain Sandstone and one of the deep poorts in the plateau. On the left there are hills of Bokkeveld slates overlying Table Mountain Sandstone.

North of the place where the narrowing of the basin takes place there is a stretch of rock attached to the side of the mountain, which is a pure crush-breccia, produced, that is, by the rock being riven and shattered till the hard beds of quartzite have acquired the nature of pounded glass. We have already noticed the same effect, for instance, at Bottel's Kop, near Mossel Bay,* and we always associated it with the Enon Conglomerate; the part the latter plays, however, is entirely secondary; it merely covered the rock while movement of the mass was taking place, and was insufficient in thickness to keep the quartzite from being shattered; the quartzite was in the zone of fracture and not of flow, as in the case where the rocks are bent without breaking. The extraordinary thing about this Baviaan's Kloof breccia is the enormous extent of it, the strip is seven miles long, three-quarters of a mile broad; and 1000 ft. high; how much more there is underground cannot be ascertained; the stupendous force requisite to smash up the material can be dimly estimated when we remember that it requires a pressure of twenty tons to the square inch to break a single cubic inch of quartzite in our testing machines. The effect of this crush-breccia on the outline of the northern border of the basin is very marked. The dip-slope of Table Mountain Sandstone comes east from Klip Fontein in an almost straight line, the regularity broken by shallow water-courses which carve the dip-slope into arches, and every now and again by the deep cleft of a gorge with perpendicular sides that cuts down to base-level. Where the breccia begins the regularity is broken and the kloofs are more numerous and wider, consequent on the easier disintegration of the broken material (Fig. 13). The best place for seeing this crush-breccia is behind the homestead in Zand Vlakte, where a cattle path is carried zig-zag up the precipitous face of the fault on to the high-level plateau. East of Zand Vlakte, on Eenzaamheid, the dip-slopes become regular, and at the end of the basin, on Mist Kraal, there is a bridge of high ground composed of brecciated Table Mountain Sandstone.

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* See Ann. Report for 1901 (p. 9).

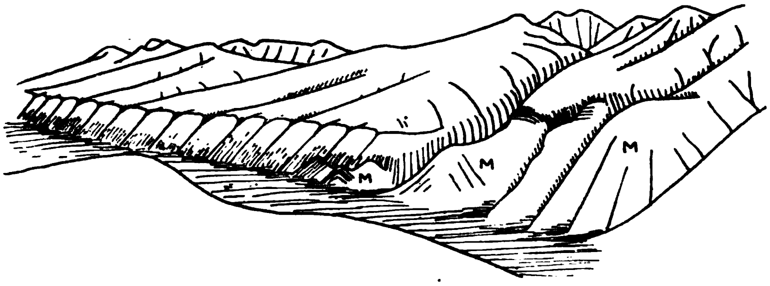

FIG. 13.—The Baviaan's Kloof Mountains by Joachim's Kraal and Rust-en-Vrede, showing the bare dip-slopes of Table Mountain Sandstone truncated on top by the gravel covered plateau, the fold-valley in the fore-ground containing Enon Conglomerate, and the brecciated quartzite M, M.

The Enon Conglomerate is not well exposed in the west of the basin, as it is covered with alluvium. By Klein Poort there is a levelled hill of White Conglomerate resting against a dip-slope of Table Mountain Sandstone, and beyond there is a wide expanse of White Conglomerate and the overlying sandy beds. Towards Rust-en-Vrede the Red Conglomerate comes in, and from here throughout the narrow portion of the basin it is very much in evidence.

At Zand Vlakte the Red Enon rests on the dip-slopes of Table Mountain Sandstone on the north, and the White Conglomerate rests on the Red, showing the edges of the irregular layers of gravel exposed in steep krantzes facing the alluvial flats of the river. Between Zand Vlakte and Eenzaamheid the whole valley closes in, and there is just a deep gorge cut in Red Enon Conglomerate; the dip follows the angle at which the Table Mountain Sandstone dips on the southern rim of the basin, and the faulting seems invariably to have occurred along the northern. The Enon Beds seems to have been nipped in the formation of the basins, as there are folds in the rock; these may be well seen in the great krantz of Red Enon near the western boundary on Eenzaamheid. No fossils of any kind were found in these Enon Beds.

It is at Zand Vlakte that the first permanent running water now exists in the Baviaan's Kloof River. At Verloren River a small stream is obtained by digging deeply in the river bed, but otherwise the streams come from the side, and are not sufficient in volume to make a runnel in the sandy bed of the main river. At Joachim's Kraal and Zand Vlakte, however, there is a vley covered with rushes in which the water lies stagnant, and issues at the further end in a fine stream. The farmers, unfortunately, are burning out the vley to convert the marsh land into fields, and the place will shortly become the same as the Beer Vley in the Karroo, that is, a dry sandy waste. The river-valley is also more steep-sided below Zand Vlakte, as if the erosion was less than that in the upper portion, and it is just possible that the Baviaan's Kloof River at some remote time turned off at Rust-en-Vrede and went through the Kouga Mountains by Tchando Kloof to join the Kouga River in the Humansdorp Division, instead of the Kouga coming, as at present, through the mountains to join the Baviaan's Kloof River lower down. The possibility is heightened by the fact that the Kouga comes through the mountains in a direct northerly course, with bends at right angles, so that it looks as if the valley was due to tectonic movements synchronous with the north and south folds that separate the Baviaan's Kloof basins, and while they opened a rift for the Kouga as it now runs, they closed up the diagonal courses of the Tchando-Joubert's Kraal River and interposed the high ground of Koude Nek between the two main rivers. In this connection also one can recall that at Beako's Nek and Klip Fontein there is evidence of a stoppage in the river which allowed the intermediate plateau to be cut; this might have happened during the change of the course of the main river from Tchando to Kruis River. At Zand Kraal and Mist Kraal there are two more perfectly straight rifts down which the Zand Kraal and Geelhout Bosch Rivers run ; as all the ground is flat on top of the plateau, a river starting to cut downwards would carve for itself a long winding channel, as do the other kloofs, and hence one is justified in bringing in earth movements to explain such straight courses as the Geelhout Bosch stream and the Kouga River above the farm Kruis River. The ground all about here is very extraordinary; it is all planed to a level about 1,200 to 1,500 ft .above the river beds, and the courses of these latter are cut down with perpendicular sides; it is the same thing that we have been noticing all along, the high-level plateau, but here it widens out and the intra-mountainous bevels coalesce by a series of ledges or steps with the high-level flats that reach near Port Elizabeth to the sea. The ground about the eastern end of Baviaan's Kloof is nearly useless owing to the labyrinth of these cañons: from the high peak by Mist Kraal one can overlook all this flat country right away to Port Elizabeth, the town itself being hidden by the Cockscomb Mountain.

At Mist Kraal there are two little pockets of Red Conglomerate left folded, like the one at Riet Fontein, in among the brecciated Table Mountain Sandstone; the dip-slopes of the latter rock on the south are closely crumpled. The last main basin begins just east of this on the farm Couga, and is a narrow band of Red Conglomerate folded in the Table Mountain Sandstone, and probably ending on the farm Kruis River. The Willowmore map, however, is useless about here, and I was unable to plot boundaries. The dip-slopes on the south and the fault face on the north are the same as in the other basins, and near the end by Kruis River there is a great outstanding block of brecciated quartzite. The end of Baviaan's Kloof is where the Kouga River joins it: the latter comes north with a straight vertical cliff of Table Mountain Sandstone on the eastern bank; it must be over 1,200 ft. high, and shows the strata dipping 45° to 60° south.

Behind Zand Vlakte and Mist Kraal, in the Baviaan's Kloof Mountains, there is a longitudinal valley of slate, which is probably a very thin band of Bokkeveld Beds folded in; it divides the range into two, not only by the depth to which it has been weathered, but also by the sweet-veld which is supported by the calcareous rocks in it. The rock is intensely sheared, and assumes the appearance of the phyllites of the Malmesbury Series. The whole double range of Table Mountain Sandstone is intensely crumpled with closely pressed bends; on the northern flanks, opposite Steytlerville, they open out into knee-bends.

THE KARROO GOLD.

Continual mention has been made throughout this Report of the high-level plateau and the recent gravels deposited on it. There is a great deal of work to be done still before one can understand the full meaning of these plateaus. In the west, there seems to be one general high-level plain on the coast which has been cut into to make the Ruggens. Eastwards, however, this plain is cut into a number of steps, and this is an essential part of the whole question, and one which has not been investigated except in Kentani and Pondoland, but it has been noticed between Port Elizabeth and Sand-flats. Below this again there is the submerged plain that continues to the edge called the Agulhas Bank, a tract of what was once dry land covered with 100 fathoms of water. The plain, of which mention has been made in this Report, is a higher one, and would correspond to the coast plateau at a time when the present coast plateau was submerged like the Agulhas one now is. The difficulty in arriving at any definite statement on the matter is caused by the want of bench-marks in the Colony, and one having to rely on eye observations from high points; it looks, however, as if towards Port Elizabeth the intra-mountainous plateau coalesces with the seaward one, the whole forming a graded plain sloping gradually from a maximum height of nearly 4,000 feet to the sea, and ending in the shore cliffs. I cannot, however, feel certain that the 4,000 feet levels, that is, the flats cut on top of the Witteberg hills around Prince Albert and Willowmore, and forming to the east the Groot River Heights, do not belong to a fourth order of plateaus, counting the Agulhas bank No. 1, the Upland plateau at Swellendam, etc., No. 2, and the Uniondale, etc., plateau No. 3. A fifth peneplain or plain of erosion, at a level of 5,000 to 6,000 feet above the present sea-level, may well have existed in addition, for many of the crests of the mountains run in straight lines as if they were remnants of such a plain.

It is impossible at present to determine whether the peneplains Nos. 3 and 4 are distinct; but whether they are so or not does not affect the important bearing that these old land-surfaces have on the question of the Karroo gold. The Karroo rocks being of such comparative recent age are unlikely to contain metalliferous deposits in any quantity; it is a universal rule that the more ancient the rocks are, the more they are likely to have cracks and crevices filled in by means of vapours or solutions bearing the heavy metal. On the other hand, the Zwartebergen, composed of Table Mountain Sandstone, has for a long while been known to bear gold in small quantities; pannings in the kloofs invariably afford some colour, the rock also is the same as that at the Knysna Gold-fields. It is also well established that in a formation made up largely of sands, that where there is a development of gravel, this deposit tends to have the gold concentrated in it. In the Zwartebergen there are beds of solidified gravel or banket, and though it is very probably but poor in gold, yet there are certain to be patches where the percentage is high. The same banket occurs in the Knysna gold area. Could we then find a mode of transport from the Zwartebergen to the Prince Albert Gold-fields, by means of which gold could have been carried from the one place to the other, it will be an almost certain proof that the Karroo gold is derived from the Table Mountain Sandstone.

North of Prince Albert there is an extensive flat, the even course of which is broken by an anticline of Witteberg quartzite that protrudes through the overlying rocks at Tygerberg. The plain slopes up to a tract of folded Beaufort Beds that occur all round Spreeuw Fontein and Waterval, the proclaimed areas. Looked at from the south-west these hills will be seen to touch a straight sky-line, which must be caused by the rocks having originally been cut down to a level plain, as they are so contorted that otherwise they would have produced a series of jagged and irregular hills. This sky-line lies at an elevation of from 3,000 to 3,500 feet above the sea-level. At Prince Albert the Witteberg hills are cut to a level of from 3,500 to 4,000 feet elevation, and also once formed part of a plain of erosion. That each of these two plains was at one time very much more extended is certain, and that they were once connected is almost certain, as the fall in height from one place to the other is about that which would be natural in a low-graded plain. We have then a high-level plateau stretching from the Zwartebergen to the Gold-fields down which in former ages the streams ran to the north carrying any metallic particles that weathered out of the Table Mountain Sandstone, and depositing them in gravelly pockets. Then we must suppose the bars to the rivers removed, probably owing to the rising of the ground and the more vigorous downward cutting induced by it. Thus the gap between the gravel-capped bevels under the Zwartebergen by Prince Albert, and the Witteberg hills, and between the latter and the hills about the gold-fields became formed, and extended till only a few remnants of the once extensive plain were left; the hills left standing then became weathered, and the softer beds were removed. In this way the gold in the gravel and sand originally capping the plain round Spreeuw Fontein became washed down into the gullies and worked its way into the crevices and joints of the rocks where it is now found.

GEOLOGICAL SURVEY

OF

PARTS OF THE DIVISIONS OF PIQUETBERG, CLANWILLIAM AND VAN RHYN'S DORP.

BY

A. W. ROGERS.

GEOLOGICAL SURVEY OF PARTS

OF THE

DIVISIONS OF PIQUETBERG, CLANWILLIAM, AND VAN RHYN'S DORP.

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The area covered by this survey extends from the Berg River, south of Piquetberg Mountain, northwards as far as the Olifant's River. The western limit is the coast between the Zout Kloof River on the farm Bokkeram and the mouth of the Olifant's River; the eastern is the mountain ground west of the Olifant's River from Compagnie's Drift to the Olifant's River Mountains at Piekeneer's Kloof. The greater part of the low ground between Piquetberg and the Olifant's River Mountains has not yet been mapped, nor has the sandy coast country between Bokkeram and Berg River mouth.

Broadly speaking, this area lies just on the outer side of the folded belt west of the Karroo. The rocks of the Cape Formation that are bent into the great western group of anticlines, of which the Cederbergen are the most conspicuous results, lie at much lower angles west of that range. The Olifant's River Mountains are much less folded, and are really the eastern limb of a low, broad anticline, of which the axis runs about 15° west of north through the low ground east of Piquetberg, now denuded of its former covering of sandstone. The eastern cliffs of Piquetberg Mountain and the western face of the Olifant's River Mountains were once connected by the sandstone. At Rhenoster Hoek the low arch of sandstone can be seen resting upon the Malmesbury Beds.

The Table Mountain Sandstone of Piquetberg Mountain is an irregular synclinal mass with low dips. On the north-west it is continuous with the great area of that rock, which lies in a gently undulating sheet over the coastal portion of Clanwilliam and also of Van Rhyn's Dorp as far as the Olifant's River.

The main lines of the gentle folds into which this great mass of sandstone has been thrown are parallel to the sharper corrugations of the Cederbergen and other ranges on the west of the Karroo, and they were probably produced at the same time, but there is such a marked contrast in the amount of folding in the two cases that the area dealt with in this year's Report can be considered as lying outside the folded belt, just as the Cape Peninsula mountains are outside it further to the south.

By the removal of parts of this undulating sheet of sandstone by denudation the older, Pre-Cape, rocks have been exposed east and west of Piquetberg Mountain and in the Verloren Valley.

Generally speaking, the whole coastal tract stretching some twenty miles inland is so far buried in sand that only the higher points of the buried surface of hard rock appear above the sand. This type of country, which is called the Sand Veld, extends from the Berg River to the Olifant's, where the sand decreases considerably in quantity.

The coast is, on the whole, an uninteresting stretch of sand. From the Berg River to Baboon Point there are no rocks seen on the shore, but near that Point (Cape Deseada) the Table Mountain Sandstone makes its appearance, and reappears at intervals as far as Strand Fontein, about five miles south of the Olifant's River. Between Thorn Bay and Strand Fontein the sandstone forms cliffs about 100 feet high, which are in many places inaccessible. Sea cliffs are not frequent on the Colonial coast, and there are none approaching these in size or ruggedness on the west coast between Thorn Bay and the Peninsula, over 140 miles further south.

North of Strand Fontein the coast is rocky at places, but the Malmesbury Beds which there appear on the shore do not resist the waves and weather like the Table Mountain Sandstone, and give rise to a more jagged coast, with stretches of sand between the points formed by the harder portions of the Malmesbury Beds.

The rivers in this district are few in number; the Berg and Olifant's Rivers receive most of their water before entering our limits; the Verloren River is the largest which lies within the district, and the Lange Valley and Jakhal's Rivers are the only others that deserve the name. The Zout Kloof River near St. Helena Fontein is a very small and short stream, but it is the only one between the Berg and Verloren Valley Rivers, a distance of thirty-three miles along the coast. The Verloren Valley, Lange Valley, and Jakhal's Rivers do not maintain open mouths throughout the year, and the Lange Valley mouth is rarely open. North of the Jakhal's River (Lambert's Bay) there is no stream which enters the sea till the Olifant's River is reached. There are, of course, several short gullies, especially near Strand Fontein, where the coast is higher than usual, but these only have water in them during and immediately after heavy rain. The river bed marked on the maps near Strand Fontein, and called the Zand Leegte,* has never had water in it since the farm was occupied, a period of perhaps 100 years. The heaviest rains that now fall do not succeed in making the water flow to within five miles of the sea, though some fifteen years ago a weak flow reached as far as that point. The lower part of this dry valley is cut about 150 feet deep into the hard quartzitic sandstones of the Table Mountain Series, and it is some 100 yards wide at the narrow places and three times that width at others, so the stream that excavated the channel must have been a fairly powerful one. The present condition of the Zand Leegte is closely connected with the formation of the Sand Veld, and will be discussed later when we consider that part of our subject.

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* For information upon this point and many others I am indebted to Mr Fryer, of Strand Fontein.

Excluding the sand and other superficial deposits, only three groups of rock take part in the solid geology of this area; the Malmesbury and Ibiquas Series of the Pre-Cape rocks, and the Table Mountain Series of the Cape System.

THE MALMESBURY SERIES.

Beds belonging to the Malmesbury Series crop out at the base of the Table Mountain Sandstone of Piquetberg and at many places in the low tract of country to the east, but in that part of the district, as in others, they are to a great extent concealed under soil and other surface accumulations. In the Verloren Valley they are very poorly exposed, and the exact nature of their junction with the Ibiquas Beds is not at present determinable. Further north they are only exposed at the edges of the narrowing area of the Table Mountain Sandstone, and it is doubtful whether any inliers exist under the sand within the boundaries of that formation.

The bulk of the rock south and east of Piquetberg Mountain is silky sericitic slate, usually decomposed to a depth of several feet from the surface, so that fresh specimens are very difficult to obtain. The decomposed rock is reddish or yellow in colour, sometimes nearly white. It is highly cleaved, but it is too sericitic, and the cleavage is too irregular to allow the rock to be used for roofing slates. The highly argillaceous nature of the slates is shown by the clay resulting from their decomposition. The gritty rocks to be mentioned below produce a sandy clay. The sericitic slates occur also to the north of the Piquetberg Mountain, along the Verloren Valley and in the two hoeks formed by Antonie's and Papenkuil's Rivers, and also on the Ongegunde coast and along the Olifant's River.

In all parts of Piquetberg the slates are interbedded with gritty rocks of various natures. Some of these are slates with numerous quartz grains in them; others contain felspar as well as quartz imbedded in a purplish compact ground-mass. All these rocks are cleaved, and from an examination of hand specimens and the rocks in the field it is not easy to decide whether certain bands are felspathic grits or crushed quartz porphyries, and no materials are at present available for a microscopic examination. The absence of granitic intrusions from this district — the nearest being the Saldanha Bay-St. Helena Bay mass— lessens the probability of the felspar grits being crushed quartz-porphyries. The quartz-porphyries known in the Malmesbury-Paarl area are not crushed, but the presence of the crushed porphyries of Stellenbosch and French Hoek shows that great earth movements affected these rocks after their intrusion, and therefore the same succession of events may have taken place in Piquetberg. The chief band of these doubtful rocks near Piquetberg runs S. 15° E., and has been traced about four miles. On the road up the mountain from Klein Vogel Valley to Mouton's Valley two rather coarse and much decomposed cleaved quartz-felspar rocks are cut through. Their strike is the same as that of the similar rock nearer Piquetberg, about 15° west of north, and in each case there is a steep (over 75°) dip to the eastwards. The Klein Vogel Valley rock is by far the coarser of the two, and if the strike is prolonged it passes nearly two miles to the eastwards of the Piquetberg outcrops, so there is not much probability of their being the same band of rock repeated by folding. The two beds on the Mouton's Valley road are, however, likely to be one bed repeated by folding.

Felspathic grits, strongly cleaved, crop out at several spots on the road side down the Verloren River. Sections from two to four feet high have been cut along this road, otherwise the rocks are almost entirely concealed under the alluvium near the river and under sand at higher levels. In the road cutting just opposite the entrance of the Papenkuil's River a good exposure has been made of an isoclinal fold, with both limbs dipping eastwards. The arch, for it is an anticline, is sharply defined. The general dip of the Malmesbury Beds in the Verloren Valley, from Witte Drift to above De Kruis, is eastwards at angles from 50° to 90°, and there is an enormous thickness of slates and grits represented in this section of 15 miles length. The fold above mentioned, however, shows that the general structure of the area may be that of an intensely folded isoclinal mass. The section showing the fold happens to be more clearly exposed than the majority of outcrops that are seen at intervals along the valley.

Gritty rocks without much felspar, but with strongly developed cleavage, are seen in several places in the valley, and are especially abundant on the mountain slopes above Olifant's Klip (Ezel Fontein on the maps). The total thickness of the cleaved grits must be several hundreds of feet, even allowing for repetition by folding.

Near the Olifant's River mouth, between the Salt Pan and the Strand Fontein spring (along the Ongegunde Fontein coast) there is a thick band of quartz-felspar grit, highly cleaved, and containing a large amount of sericite in minute flakes parallel to the cleavage. The quartz and felspar grains are without definite shape so far as one can determine them in a hand specimen. The bulk of the matrix is a white quartz-schist, not unlike the schists on the Gwayang's River in George. Other parts are more argillaceous. The cleaved grits lie between highly contorted sericitic phyllites and a thick band of less contorted phyllites. They contain numerous veins of quartz, such as are abundant in the other outcrops of Malmesbury Beds throughout this area. These have occasionally been broken up so thoroughly that the rock appears to be a conglomerate. The quartz fragments are of various sizes up to four inches in diameter. The larger fragments are about two inches in thickness, probably the thickness of the vein which has been crushed. The pseudo-boulders lie with their long axes in the plane of schistosity or cleavage, and the surface of a boulder is often coarsely striated, especially towards the ends of the spindle-shaped pebbles. To each end is often attached a brush-like arrangement of quartz-schist, which only becomes apparent when the boulder is knocked out of the matrix. They have a pulled-out appearance, and were certainly formed by the breaking up of a zone of quartz-schist traversed by several thin quartz veins. At several spots on the cliffs veins can be found partly broken up, and as we shall have occasion to mention later on, some thin beds of quartzite in the slates nearer Strand Fontein have suffered a similar disruption. The appearance of the weathered surface of this rock is identical with that of a sheared conglomerate, *e.g.*, the sheared conglomerates of the Cango Series. The absence of all other varieties of rock than vein quartz in the pebbles makes one suspicious of the Ongegunde Fontein conglomerate, and the finding of the partly broken veins in the same beds removes any doubt as to their being true crush-conglomerates. Very similar gritty rocks crop out along the Olifant's River at Naast Drift, where they overlie the whitish crystalline limestone or marble of Vredendal and underlie the great body of sericitic phyllites seen at Bakkely's Plaats and Melkboom, where the marble comes in again on the left bank of the river. Although the rocks appear to be just as much crushed in the Olifant's River valley as along the coast, they lie at lower angles.

Pure quartzites are not abundant in the Malmesbury Series, but rocks consisting largely of a fine-grained mixture of quartz and white mica are not infrequent. A thick band of these has been traced from Witte Water, south of Piquetberg Mountain, in a south-easterly direction to the Berg River above the road bridge. The quartzites then cross the river, and are probably continued into the Malmesbury Division. The dip of this band is about 20° east of north, and agrees on the whole with that of the sericitic phyllites and grits with which it is interbedded. In Verloren Valley quartzites or quartz-schists are not frequently met with, though some thin bands are exposed in a road cutting near De Kruis, on the left side of the river.

On the Ongegunde Fontein coast micaceous quartzites form thick groups of strata near the uppermost limit of the exposed part of the Malmesbury Beds. They are much traversed by vein quartz. These beds are whitish in colour; they are of no particular interest. There are some thin beds of quartzite lying between soft slates, reaching a maximum thickness of two inches. The belt of soft slates lies between two thick groups of quartzites, and has evidently suffered very much from pressure on that account, as the thin beds of quartzite are much twisted and broken, while the similar rock of the thick quartzite groups above and below show no other effect of the pressure than the development of a schistose structure. The dip of the thin quartzite bands, and of the lines of broken fragments derived from them, is considerably higher than the inclination of the cleavage. The former dip at about 70° to E. 5°—10° S., while the latter dips 45° towards E. 15° S. The intersection of the cleavage and bedding planes is often marked by an abrupt twist of the latter, sometimes going so far as to be a reversed fault with overthrust of an inch or two. A few beds are converted into pseudo-boulders, owing to the complete disruption of their material by numerous small thrust planes. The pebbles thus produced resemble the pseudo-pebbles of vein quartz in the phyllites at a somewhat lower horizon. The process has not proceeded nearly so far in this case as in that of the quartz veins, and therefore the rock can hardly be taken for a conglomerate; but the two occurrences are of quite the same nature.

On the hill above Klein Vogel Valley, about four miles north of Piquetberg village, there is a zone of crushed rock four feet wide. Angular fragments of vein-quartz are embedded in a slaty matrix, which is a broken-up slate, not a schistose rock. The quartz fragments in this band are very different in appearance from those of the Ongegunde coast, for they are not in the least rounded by severe pressure, or solution brought about by the pressure, and the breccia was evidently produced by different means from those through which the Ongegunde pseudo-conglomerates were made. The Vogel Valley rock is probably a fault-breccia, though no slickensides could be found, and the rock on either side is the same, a fine sericitic phyllite. The breccia, too, lies parallel to the bedding and cleavage of the slates, but only three feet of rock is seen at the exposure, and it cannot be traced across the débris-covered hill-sides above or below.

Limestones in the Malmesbury Series are found in the Piquetberg district at two localities. On the farm De Hoek (Riet Fontein on the divisional maps) a band of bluish crystalline limestone has been traced over a mile in a south-easterly direction from the mountain, where it is overlain by the Table Mountain Sandstone. Its strike is approximately parallel to that of the silky slates amongst which it lies. It crops out on the road from Piquetberg to Witte Water, and at a few spots in the veld on either side of the road; near the railway at De Hoek it is quarried and sent to the Peninsula for glass-making. The width of the band is about 300 feet.

On the farm Kley Gat, in the hoek between the Kapitein's Kloof Mountain and the ridge between Ezel's Hoek (Het Voetpad) and Wilgebosch Drift (Wilgenhout Drift on the maps), there is a very similar belt of limestone with the same trend as the Hoek rock, but lying two and a half miles further northeast than the line of prolongation of the Hoek beds. It is likely that the two occurrences belong to the same bed. At Kley Gat the limestone forms insignificant outcrops, as the soil is thick and there are but few exposures. Its thickness could not be ascertained closely, but it exceeds 100 feet.

No other outcrops of crystalline limestone are known in the district, but it is a rock that can easily be overlooked for it is dissolved by the surface water and generally crops out less readily than the slates and grits. Along the Olifant's River whitish and blue limestone is seen at intervals between Vredendal and Melkboom. At Vredendal it forms vertical cliffs rising sheer from the water to a height of fifteen feet, and at Naast Drift it is seen on the left bank. At Melkboom (that part of Bakkely's Plaats within the sharp loop of the river) the whitish limestone is inter-bedded in thin layers with a gritty slate. The limestone along the river dips at moderate angles south-westwards. Its thickness is unknown, but an examination of the lower parts of the Troe Troe River will probably allow an estimate to be made. The Vredendal marble is almost certainly the continuation of a similar rock near Aties, and probably the same rock as the Van Rhyn's Dorp marbles brought to the surface again by folding.

Quartz veins are rather abundant in the Malmesbury Beds throughout this area. Most of the veins are small and irregular, but there are large ones which can be followed for considerable distances on the surface. On the farm Vondeling, near the road bridge over the Berg River, a thick quartz vein follows the strike of the micaceous quartzite belt spoken of above rather closely. This vein is at least three miles in length, and at places it is ten feet wide. Two considerable veins run at right angles to this one, but are of less extent. The thick quartz veins naturally make conspicuous ridges, on account of their resistance to the weather.

At Schrik Van Rondom a thick quartz vein makes a prominent hill on the right side of the Verloren River. The vein traverses the slates vertically and trends S. 30° W. A prospector made a tunnel 150 feet through the kopje in order to strike the vein at a point some distance from the surface. No results worth the trouble and expense of making the drive were met with, but quite as valuable information could have been obtained by sinking on the vein itself, for it is admirably exposed on the top and on two sides of the hill. The quartz obtained from near the surface would have given all the information required to determine whether further expense should be incurred. The wash from the hill would also have given a safe indication. In this case, however, as in several other unsuccessful ventures, the ruling idea was that a rock which is perhaps worthless at the surface may contain untold riches at a depth only reachable by the expenditure of much money. The presence of small quartz veins throughout the slates is indicated by the innumerable fragments of vein-quartz lying in the soil derived from the slates and other beds in the Malmesbury Series.

There are two classes of quart zveins in the Malmesbury Beds of this area, formed respectively before and after the chief earth movements had taken place. To the earlier group belong the veins which have been broken up, and which thus gave rise to the crush-conglomerate on the Ongegunde coast, and many other veins that were bent and broken at the same time that the phyllites and other rocks were distorted. But in addition to these there are veins traversing the same rocks and apparently quite undisturbed by the movements which affected the latter. To this latter group belong the large veins of the south end of Piquetberg, and probably also that on Schrik Van Rondom.

Some quartz veins in the phyllites near the Olifant's River marbles contain chalybite, carbonate of iron. Small nests of a green mineral, chlorite, are frequently seen in the older group of veins. Some desultory prospecting for gold has been carried on in various parts of the district without favourable results.

On the Olifant's River the limestones lie below the phyllites and gritty beds of Naast Drift and Bakkely's Plaats, but there is no evidence obtainable as to the correlation of this limestone with that of De Hoek or Kley Gat. On lithological grounds the two groups of marble beds might be considered quite distinct from one another. The white limestones of the Olifant's River and the pale blue micaceous rock of the Troe Troe River cannot be matched in Piquetberg.

No fossils have been found in the Malmesbury Series, although some of the limestone beds along the Olifant's River look as if they might contain them. Probably the process of re-crystallisation has obliterated all traces of fossils.

The Van Rhyn's Dorp and Piquetberg limestones do not contain any chert beds like those associated with the Campbell Rand and Malmani dolomites of the north, and there is no close resemblance between them either in respect of the limestones themselves or the rocks above and below..

THE IBIQUAS SERIES.

In the Annual Report for 1900 this term was introduced for certain beds older than the Table Mountain Sandstone and younger than the Malmesbury Beds in the north-east of Van Rhyn's Dorp and the west of Calvinia. There the Ibiquas Beds crop out along the face of the Bokkeveld escarpment and in the basin-like hollow behind the Stink Fontein Poort. During the survey of Piquetberg some peculiar rocks were met with below the Table Mountain Sandstone in Verloren Valley, and from the fact that they differ very greatly from the Malmesbury Beds in being much less affected by earth movements and other causes that gave rise to the intense folding and metamorphism in the latter, they must be looked upon as younger than those. There is no other reason for correlating those beds with the Ibiquas Beds than their evident intermediate position between the Malmesbury and Table Mountain Series, and a certain lithological resemblance between the two occurrences. The nearest typical Ibiquas Beds lie some 46 miles north-north-west of the Verloren Valley outcrops, and most of the intervening ground is still covered with Table Mountain Sandstone.

The plan on the next page shows the position of the only two outcrops of those beds in the Verloren Valley, and their relation to the older and newer formations. The scale is too small to allow the dips to be shown, but as the outcrops are in the axis of an area disturbed by faults, near which some crumpling of the beds has taken place the dips are not of much importance from a stratigraphical point of view.

The Verloren River in this neighbourhood runs approximately along an anticline which is broken down on the north-east side. The anticline trends about N. 30° W.

The exposure of the Ibiquas Beds on the left bank of the river on Witte Drift lies at the foot of a sandy slope, above which rises a conspicuous ridge of Table Mountain Sandstone. The Ibiquas Beds here consist of reddish sandy shales with thin beds of sandstone; they dip westwards at from 15°—30°. On all sides they are surrounded by sand and alluvium.

The second area is about two miles above Witte Drift house (situated near the junction of the small stream from Kruis

Fontein and Verloren River); on the north-west the Ibiquas Beds are in contact with the Malmesbury for a few hundred yards, but no clear evidence could be found of the nature of this junction. The first outcrops are met with over 100 yards

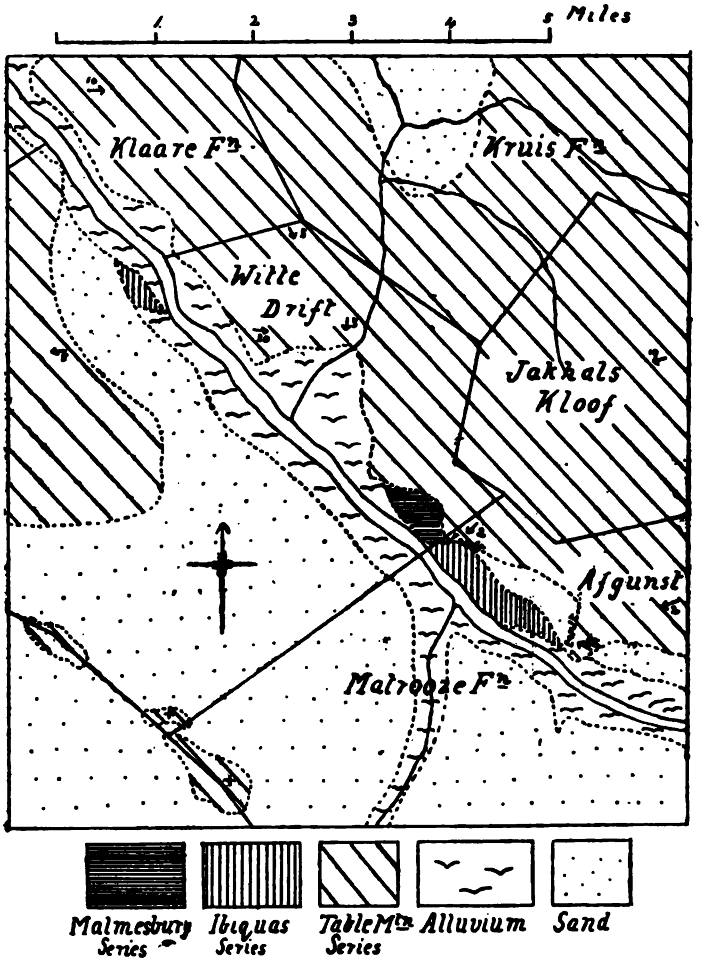

FIG. 1.—Map of part of the Verloren Valley to show position of the Ibiqua's Beds.

from the Malmesbury Beds, and the intervening ground can only be mapped in by the help of fragments in the soil. The Malmesbury Beds on Witte Drift are sericitic phyllites much veined by quartz and strongly cleaved. The general dip of the cleavage is E. 10° N. at high angles. The difference between these beds and the sandstones and shales of the Ibiquas is very great. The sandstones are greenish or dull red in colour; they are very gritty with flakes of mica of detrital origin. The first outcrops seen have a moderate westerly dip, and the rocks are chiefly sandstones. About 200 yards further south-east, beyond a belt of soil which completely hides the underlying beds, we come to red marly shales with beds of greenish sandstone from one to five inches thick. They are very much folded in a most irregular manner, owing to their proximity to the fault previously mentioned. The red shales are not cleaved, and although they are slightly micaceous the mica was derived from older rocks and was not developed in the shales as the sericite was developed in the phyllites. The shales break with a sub-conchoidal fracture after the manner of the less altered parts of the thickly laminated shales of the Ibiquas group in Calvinia or those of the Bokkeveld Beds. The greenish sandstones indicate very clearly the course of the folds on a red patch of bare rock near the main road on Matrooze Fontein. At one place the beds are folded into a boat-shaped anticline, with its axis running north-east and pitching steeply to the south-west. At the north-east end, which is incompletely exposed, for the sand encroaches upon the red patch, the beds are twisted back upon themselves by a slight over-thrust from the south-west. Almost the whole outcrop of a certain horizon affected by these folds is marked by a 3-inch bed of green sandstone, which forms a closed oval in plan. Parallel with this anticlinal axis there are several dip-faults of small throw, which tend to shift outcrops further and further towards the north-east as the ground is traversed in a south-easterly direction.

The whole area is certainly a mile and a half in length, but exposures cannot be found throughout. To the north-east a belt of sandy veld separates it from the nearest outcrops of Table Mountain Sandstone. This sandstone crops out at a level of from 50 to 100 feet above the river as a rule, but at the point approaching the river on Afgunst it descends to the level of the water. There is a transverse fault here with downthrow to the east; this fault is almost at right angles to the dislocation on the north-eastern side of the Verloren Valley anticline. Near the north-western end of this area the Ibiquas Beds and the Table Mountain Sandstone crop out very near each other; the sandstone appears as a wall of truncated strata rising some 30 feet above the older rock, with a slight dip towards it. The wall is the face of the Verloren Valley fault, which is mostly concealed below the superficial deposits. To the south and west of the Ibiquas Beds are the alluvial deposits along the river, and a wide tract of sand intervenes between the river and the Table Mountain Sandstone on the Matrooze Fontein boundary.

THE TABLE MOUNTAIN SERIES.

These beds form by far the greater part of the rock at or near the surface of our district.

On the east are the minor anticlines of the Cederberg group, but of considerably less size than the main Cederberg anticline. At the south end of the district there is the western limit of the Olifant's River syncline, forming the escarpment bounding the low ground of Piquetberg and Porterville; the crest of the low anticline, as we have already had occasion to mention, has been removed, and part of its western limit is preserved in the Piquetberg Mountain. The western limb of the syncline is known as the Olifant's River Mountains. North of Rhenoster Hoek this range joins up with the western stretch of sandstone to form the broad anticline which extends some 36 miles northwards, and dies out imperceptibly. This mountainous country is divided up by transverse, or rather diagonal, valleys, produced by subsidiary folds, into various ranges, of which the chief are the Zwart Berg, Lambert's Hoek Berg, Kaffirs' Kraal Mountains, Krantz Valley Mountains, Rhenoster Berg, Baviaan's Berg, Lang Berg, and Groot Zwart Berg. The highest point in these ranges is the top of Lambert's Hoek Berg, 3,598 feet,* 2,742 feet lower than the Cederberg crest.

The outstanding masses of sandstone known as Klip Fontein's Berg, Heeren Logement's Berg (2,379 feet), and Konaqua's Berg are not situated on definite anticlinal ridges, but have been left standing after the removal of the surrounding rock by rivers. In the case of the other mountains denudation has, of course, played a very great part in their formation as we now see them, but they are portions of arched folds.

The general course of the low anticline west of the Olifant's River is about N. 15° W., but the subsidiary folding, which has to a certain extent cut the broad fold up, trends nearly N.N.W. Although these corrugations in the rocks are sufficiently great to make important surface features, they do not bring down the top of the Table Mountain Series, and consequently the lower beds of the Bokkeveld group, to the level of the present surface. No outliers of these beds have been met with on the west of the Olifant's River valley, and it is very improbable that any will be found there. The only place where they can well exist is under the Sand Veld, but as a fault of great throw would be necessary to bring them into that position, and as no fault with a greater throw than about 300 feet is known west of the river, it is unlikely that there should be a greater one in the Sand Veld, where all the observed dips point to the dying out of the folds in that region. The deep syncline of the Olifant's River and the north-north-westerly syncline and fault of Clanwilliam bring the

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* Sir D. Gill, Geodetic Survey of South Africa II., 1901.

Bokkeveld series down to the level of the valley bottom, and probably to below the level of the sea; these folded outliers are the westernmost areas of the Bokkeveld group in the Colony.

The Piquetberg Mountains are a V-shaped mass of Table Mountain Sandstone. The left limb of the V, partially buried under sand, is continued to Baboon Point, and thence stretches across the Verloren Valley to the north end of the district. The right limb terminates on T'Wagenpad, where a narrow nek separates it from the large outlier of sandstone overlooking the Verloren Valley at De Kruis. At the extreme south end of the mountain the sandstone has been let down by a fault trending W. 10° N. against the Malmesbury beds for a distance of rather over a mile, but with this exception the outer boundary of the mass shows a well-defined unconformity. Part of the western face has not yet been examined, and beyond Klip Fontein the junction is certainly buried under sand. On the eastern and south-western edges the sandstone dips inwards at angles varying from 1°—20°, but they are usually below 10°. The western escarpment is steep and rises to a height of about 2,500 feet in Zeebra Mount. Behind this ridge the streams collect into two main channels, which cut through the eastern ridge at Boschjesman's Kloof and Plaat Kloof, and enter the Berg River. The water from Zeebra Mount runs away to the north and enters the Verloren River. The eastern ridge of the mountain trends nearly north-west, and the strata dip towards N. 35° E. on the average. The axis of the broad syncline lies nearer the eastern than the western limb, but a large part of the sandstone within the V is nearly horizontal. Towards the north there is a second syncline lying near the western limit, but its presence has not prevented the trough from being worn through by the Antonie's River, which has exposed the underlying Malmesbury Beds from Mouton's Hoek to the Verloren River. The western limit of this anticline is broken by a N. 10° W. fault, which runs past Grys Kop and probably bounds the tongue of sandstone which forms Zand Berg, but the junction of the sandstone and older phyllites is concealed under the sand north of Namaquas Fontein. The Zand Berg tongue divides the area of Malmesbury Beds within the V into two. The western or Mouton's Hoek division has just been mentioned. The eastern or Papenkuil's Valley division is a broad anticline broken through by denudation. A north and south fault through Kley Gat with downthrow to the west has brought down an outlier of Table Mountain Sandstone 300 feet at the most east of Kley Gat homestead. The Malmesbury Beds are, of course, affected by this fault, but owing to their steep dip and to the fact that their strike is only some 20° to the west of north, their outcrops are not much displaced by the fault. The western limit of the low ground of Papenkuil's Valley is rather irregular in form, and no outcrops are exposed below the low krantz of Table Mountain Sandstone that appears at intervals from Kley Gat to the south end of Lange Fontein, where it disappears under white sand.

To the north-west there are five conspicuous sandstone kopjes projecting above the sand between the Drie Fontein mass and that which stretches from Klip Kop to Cape Deseada or Baboon Point. The strata in these kops lie nearly horizontally, and the mass which forms Baboon Point has very low dips; a great part of it is composed of flat beds.

The Verloren Valley coincides in position with a north-westerly trending anticline, the roof or arch of which has disappeared. At the north-western end of the area of Pre-Cape rocks on Witte Drift the anticline is distinctly defined, though as the river cuts through the arch the actual continuity of the two limbs is broken where the rock can be seen, and there are no outcrops visible in the river bed. Towards the south-east at De Kruis the arch is completely worn through and the Malmesbury Beds are exposed. The south-western limb of the broad fold is seen in the western limb of the Piquetberg V. The north-eastern limb is in part represented by the sandstones of the Clanwilliam-Piquetberg boundary north of De Kruis, but it is less simple that the corresponding portion below Witte Drift, for there are faults near the axial line which have let down the rock to the north-east, and, as we have had occasion to note when dealing with the Ibiquas group, the rocks are much disturbed near these faults. The thick-bedded, rather massive sandstones of the Table Mountain Series are much less disturbed than the softer shales and mudstones below.

To the north of the Verloren Valley anticline the rocks are very slightly folded. They crop out at intervals through the sand, and the only continuous outcrops of considerable extent are met with on the hills on each side of the Lange Valley and in the Jakhal's Valley (the Lambert's Bay River). The folding throughout this region between the Verloren Valley and the Olifant's River is so slight, with the exception of a narrow strip near Strand Fontein, that at many outcrops the exposures are not sufficiently good to allow one to determine the dip accurately in the strongly false-bedded sandstones. The separate outcrops in the Sand Veld are at least forty-five in number, some of them so small and low that they are only detected if one happens to walk on them, but most of them make conspicuous kopjes. Although their distribution is rather irregular, the majority can be grouped into two main areas. One occurs south of Jakhal's River, and is a ridge partly buried under the sand, only the tops of the hills appearing; the second represents the hill tops of a ridge of sandstone trending northwards from Van Putten's Vley. There is no need to enumerate all the individual kopjes.

Wolve Berg, south of the Lambert's Bay main road, is an example in the southern group, and Rhenoster Klip and Klipheuvel are two good instances from the northern group.

The western boundary of the Table Mountain Series leaves the coast at Strand Fontein, and is cut through by the Olifant's River below the homestead at Fishwater. For a distance of rather more than 2½ miles south of Strand Fontein the sandstone dips eastwards at an angle between 15° and 45°. The highest dips are seen near Strand Fontein, and the dip becomes less and less southwards till at Thorn Bay it is no more than 10°. At one point between Thorn and Donkin's Bay the dip again rises to 20°. In the inland outcrops the dips are very low, and in the continuous section afforded by the Zand Leegte the strata are seen to become horizontal within three miles of the coast; at a higher outcrop and at Rhenoster Klip the beds dip at low angles westwards.

Between Thorn and Bamboe's Bays there is a small patch of very much disturbed rock. For about 100 yards along the shore the bed dips in various directions from north-west, round by north to east. There are numerous small faults parallel and at right angles to the strike of the rocks ,and at places the hard quartzite has been broken up to form a crush breccia. A quartz conglomerate, which is seen in its normal condition at Thorn Point, has suffered brecciation in this locality. At a spot on the left side of the Zand Leegte, about 5½ miles from Strand Fontein there is an outcrop about 300 yards long of brecciated quartzite; the contact with the normal rock is not seen, but as the Zand Leegte beds and those of Rhenoster Klip are nearly horizontal, this brecciated rock probably marks the outcrop of a fault.

Between Strand Fontein and Fishwater the contact of the Table Mountain and Malmesbury Series is not exposed. It is probably an unconformity. At both the places mentioned springs issue from the probable position of the junction. On the eastern side of the Sand Veld the unconformity at the base of the sandstone is easily located, owing to the sudden change in the nature of the surface soil, but the Malmesbury beds first crop out at some distance from the overlying rock between Kariep and Karroo Vlakte. North-west of Karroo Vlakte the sand and alluvium conceal both groups along the line of junction and for some miles on either side.

The nature of most of the Table Mountain Series in our area is in no way different from that previously described from other south-western districts. The rock is mainly a rather coarse sandstone, frequently becoming quartzitic by the presence of a hard silicious cement between the sand grains. About 200 feet above the base of the series in the Piquetberg mass there is a thick band of red sandstones and shales. The sandstones are finer and contain more clay than the bulk of the grey weathering rock above the band. Both the sandstone and shale are ripple marked, and the surface of some beds is covered with a network of re-filled cracks, evidently sun cracks on the mud or muddy sand, which must have been laid bare shortly after its deposition. The cracks are filled with material identical with that of the overlying bed, in many cases somewhat different in texture, but very similar in colour to that of the sun-cracked rock. These red rocks are well exposed in a small quarry in the Water Kloof just behind the village. Elsewhere they are only found with some difficulty, owing to their weathering more rapidly than the higher beds; their position is, in consequence, marked on the hill slopes by a belt of debris-covered ground. The red shaly band is about 100 feet thick at Piquetberg. In several parts of the district, near De Kruis, on the hills north-east of Verloren Valley, and on the left bank of the Olifant's River below Kariep, where the lowest 300-400 feet of the series are exposed, there is no thick shaly band, but there are thin bands of shale and argillaceous sandstone at some of these localities. On the Strand Fontein cliffs the clayey beds have weathered out deeply, and give rise to conspicuous ledges overhung by the hard quartzite of the succeeding bed. The thickness of these soft beds is not more than 5 feet. At Bamboe's Bay there is a band of red and white sandy laminated shale, 50 feet thick, interbedded with the quartzites, but this group of strata lies considerably higher in the series than the Piquetberg shales, probably over 600 feet from the base. At Heeren Logement's Berg there is a group of red shale and thin red sandstones, like the Piquetberg beds, nearly 100 feet thick. The exact position of these beds is impossible to estimate closely, but they are far higher in the series than the Piquetberg shales, and probably lie at least 1,000 feet above the base of the series.

The Table Mountain Series is, on the whole, more conglomeratic in this area than in any other part of the Colony yet mapped. The conglomerates are well exposed on the road-side in Piekenier's Kloof, and here lie at the base of the series. On the east face of Piquetberg Mountain the sandstone is not conglomeratic at the base, and with the exception of thin layers of white quartz pebbles, no conglomerate was met with in the eastern limb of the V-shaped sandstone area. In the western limb conglomerates are well developed in the mountain side above Witte Water; they are over 100 feet in thickness, but this includes beds of ordinary sandstone. Quartz and slate are the usual rocks met with as pebbles, but large pieces of red jasper occur also. A large Table Mountain Sandstone hill on the boundary between Aries Hoek and Uithoek, on the right side of the Verloren Valley is mostly composed of beds of conglomerate. The beds with small pebbles, not more than an inch in diameter, contain rolled pieces of vein quartz only, but the coarser beds with pebbles up to six inches in length contain many varieties of rocks, quartz, white quartzite, a dark grey quartzite with thin bands of white rock traversing it, red jasper, hard shales, and, rarely, granite. The pebbles have a marked tendency to occur in thin layers, often only one pebble thick, so that between two beds of pebbles there are several feet of ordinary coarse sandstone. The surface of the conglomerates has the appearance of a roughly-laid cobble pavement, so closely packed are the oval stones. At Baboon Point and Rheebok's Plaat, the flat ground on top of the hill which ends abruptly at the Point, there is much conglomerate. The whole thickness of the rock exposed below the beacon is over 600 feet, and this is made up of sandstones and thin beds of conglomerate. The thickest bed of conglomerate noticed was 8 feet from top to bottom. Quartz boulders are the most numerous, quartzites are fairly abundant, and a few red jasper and slate pebbles were seen. No granite or other igneous rock was noticed in these boulders. Similar beds of conglomerate occur at places between the coast at the Lange Valley mouth and Lambert's Bay.

The development of the conglomerates in this district is not sufficiently marked to throw much light upon the position of the land from which the Table Mountain Sandstone in the Colony was derived. As we have seen, the base of the Series is not conglomeratic throughout the area, and though the conglomerates are more abundant in the lower part of the Series, as at Piekenier's Kloof, Baboon Point, and the Aries Hoek hills, than in the higher beds seen at Klip Fontein's Berg, Heeren Logement, and the hills to the S.S.E. of that neighbourhood, yet the lower beds of the Piquetberg mass, and those exposed near the Olifant's River do not contain more pebbles than one is accustomed to see in the Cederbergen and the great ranges south of the Karroo.

RECENT OR SUPERFICIAL DEPOSITS.

These rocks play a very important part in the geology of our district. They are chiefly developed on the western side of the Piquetberg range and west of the anticlines from Rhenoster Hoek to Nouwkous. This large tract of country is known as the Sand Veld from the general sandy nature of the surface. In Piquetberg, east of the mountain, along the Verloren Valley, at a few spots in the Jakhal's River valley, along the Olifant's River, and on the coast between Fishwater and Thorn Bay, there are patches of hard quartzites resembling the rocks called surface-quartzites in former Reports. In addition to these, surface limestones are not infrequently met with, especially in the neighbourhood of the coast sand. Ironstone (laterite) is developed in places. The Saltpans have a group of deposits peculiar to them.

These deposits will be described in the following order:—

1. The sand of the Sand Veld and associated rocks.
2. Surface quartzites of the inland portions of the district.
3. Ironstone (laterite).
4. Alluvium.
5. Pan deposits.
6. Modern beach deposits.

(1). From the banks of the Berg River northwards to the Olifant's River the country is covered with sand, excepting those outcrops of the underlying rocks laid bare in some of the river valleys or projecting through the sand.

The sand varies in colour in different situations. Along the coast there is a range of dazzlingly white sand hills from 400 yards to a mile in width. Where the ground rises rapidly from the shore, as at Rheebok's Plaat and the Strand Fontein cliffs, the dunes are absent. The coast sand contains a large quantity of carbonate of lime in the form of broken shells. Behind the dunes there is a belt of greyish white sand in the lower parts of the coast district. Some clay is mingled with the sand, and where shallow sections can be seen the sandy clay is usually found to be well bedded. In many parts of this greyish white strip, which is rarely more than 200 yards wide, there are small vleys filled with salt water in winter time. They are rarely used as salt pans. The rain water tends to collect in this belt, owing to the dunes being rendered partially impervious by the deposition of calcareous matter between the sand grains. The Papen Dorp Salt Pan is the largest example of this type of vley. It is over 1,300 yards long, and about 300 yards wide. Salt is obtained from it by digging trenches, in which the water can deposit a greater thickness of salt than elsewhere. Below St. Helena Fontein the Zout Kloof stream, which runs during the winter, has been diverted into a vley to the north of the former outlet of the stream. From this vley the water escapes at low tide by percolation through the sand. The water is brak, but does not contain enough salt to leave a deposit in dry seasons. Small salt vleys which contain water at irregular intervals, but not every year, exist to the north of the St. Helena Vley. The salt in this water comes indirectly from the sea. Every particle of sand blown landwards carries salt with it, and every strong sea breeze blows spray from the waves on to the land; the rain water collects this salt from the surface, and carries it to the vleys behind the dunes, together with the finer particles of sand and clay.

Behind the greyish white sand belt comes the Sand Veld proper. The sand is pink or yellowish in colour, owing to the oxides of iron and other substances present in small quantities. There is practically no calcareous matter in this pink sand, which consists of quartz grains, with a very small quantity of black iron ores and zircon. The grains are in part completely rounded, the others are only partially rounded or quite angular.

The depth of the covering of sand varies considerably, but it is impossible at present to get a close idea of the maximum depth. There are but few wells in the Sand Veld, for each well has to be lined to prevent the sand falling in, and the trouble and expense of this process seems to deter the farmers from sinking wells, especially as several unsuccessful wells have been sunk in the district. To the west of Klein Tafel Berg in Piquetberg a well was sunk 45 feet through the sand, when a layer of stones was met with and water obtained. From the description, for none of the stone could be found during my visit, they were probably lumps of limestone formed at an earlier stage in the history of the Sand Veld, or cemented by carbonate of lime from percolating water. North of Jakhal's River on Kook Fontein a well was sunk 40 feet through the sand and 45 feet through a quartzite (Table Mountain Series) without any water being struck. Further north a well was put down 40 feet through sand, when fresh water was obtained. The solid rock underlying the sand was not struck at this place, a part of the farm Harde Vlakte. Some distance up the Zand Leegte there is a well in the dry valley, here partly filled with sand. The following section was given me by Mr. Fryer, who put down the well, and on whose property it is:—

Sand, 14 feet.
Clay, 55 feet.
Sandstone, 3 feet.
Sand, 13 feet.
Quartzite of the Table Mountain Series.

These few wells were the only ones I could get exact information about. They show plainly enough that the depth of sand and other superficial deposits is very considerable. The whole of the Sand Veld is, in fact, underlain by an old land surface buried to a greater or less depth under the sand. The sandstone kopjes projecting from the sand are the tops of the buried hills.

The average depth of sand is perhaps 40 feet, but without much more information than we have at present this is uncertain. Forty feet is a low estimate. The level of the tops of the Strand Fontein cliffs is about 100 feet above the sea; the country behind the coast, at a distance of four miles from it, lies between 500 and 650 feet above sea-level. The highest points are the tops of the sandstone kopjes, and the lower parts are sand covered.

The curious dry valley called the Zand Leegte, which has already been referred to, gives a sure indication of the events that have brought about the development of the Sand Veld. This valley can be followed over ten miles inland from the coast before it becomes indistinguishable from the slight undulations of the Sand Veld. Near the mouth it is rather over 100 feet in depth, and has been cut out of the solid sandstone of the Table Mountain Series. It is slowly being filled up with sand, which is carried there by the wind and by rain. The heaviest rain that now falls in the district does not wash the sand down to the sea, it merely serves to bring about the accumulation of the sand in the valley. As stated on a previous page, the water in the Zand Leegte has not been known to flow as far as the mouth since the district was occupied by Europeans.

There is no doubt that the process of obliteration of the surface inequalities by sand accounts for the formation of the Sand Veld. The sand is derived from the Table Mountain Sandstone, and as there is insufficient water to carry the products of disintegration of this rock to the coast, the sand accumulates in the Sand Veld between the mountains and the coast.

In the mountainous ground east of the Sand Veld there are many patches of white quartz sand, similar to the pink and yellow sand, except in colour. It may be that the colouring matter, being contained in very fine-grained argillaceous material, reaches the low ground in greater quantities than it does higher patches of white sand, from which it would be easily removed by the wind. In the Sand Veld a fine red dust accompanies the strong easterly winds that blow during the summer months, but it is not easy to ascertain whether the whole of the dust comes from the Sand Veld itself, or whether some of it is derived from the country to the east, where the Bokkeveld and Malmesbury Beds of the Olifant's Valley might furnish it. The supply of red dust from the Table Mountain Sandstone during a moderate period must be small, but the ferruginous colouring matter in that rock would in time be capable of giving the red tint to the Sand Veld if the bulk of the supply was not blown or washed into the sea. In the mountains themselves the red matter is not allowed to accumulate as quickly as the sand, so white sands are abundant there.

On the coast near Strand Fontein sections over 50 feet in height through the superficial deposits lying upon the Malmesbury Beds are exposed in the cliffs and in two steep ravines. The nature of the rocks exposed is not identical, nor is their order of succession quite the same in any two sections. In the ravines there are thin layers of grey sand containing lignite interbedded with yellow and reddish sand and clay. Pebble beds are present, but they are not extensive. At or near the base of the sand there is at places a layer of more or less ferruginous quartzite. The yellow sands are distinctly, though irregularly, bedded, and the quartzites are also bedded. The quartzite varies from a pale yellow-brown rock to a very dark red one. The darker the rock is the more iron it contains, and at the same time it becomes less quartzitic; when the yellow rock is broken the new surface passes through and not round the quartz grains, but in the case of the most ferruginous portions of the rock the fracture passes round the quartz grains. A hand specimen may be obtained showing the two varieties of rock. In places there are numerous pebbles in the quartzite. The two sections, Figs. 2 and 3, show the manner in which the sands and quartzites occur north of Strand Fontein. The thickness of the quartzite varies, but may be as much as 20 feet. Its upper surface is often irregular, as though silicification had proceeded further in some places than at others. For some two miles south of Strand Fontein the cliffs cut out of solid rock rise considerably higher than to the north, and there is but a thin layer of superficial deposits lying upon them. The greatest thickness of these deposits observed at any point on these cliffs was 10 feet. At the base is a conglomerate with sandy matrix

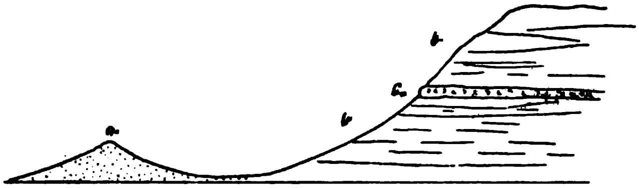

FIG. 2.—Section through a sand cliff 1 mile north of Strand Fontein.

a. Modern dune-sand.
b. Bedded sand in the cliff.
c. Ferruginous quartzite.

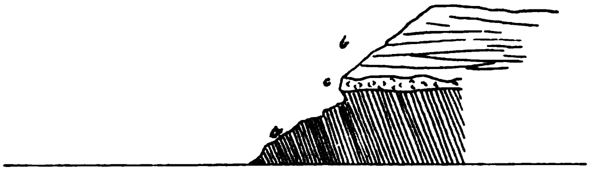

FIG. 3.—Section through cliff 1¾ miles north of Strand Fontein.

a. Slates of the Malmesbury Series.
b. Sand.
c. Ferruginous quartzite.

strongly impregnated with oxide of iron; the pebbles are of all sizes up to a foot in diameter, and consist of a considerable variety of rocks, sandstones, quartzites, schistose quartzites, granites, quartz-porphyries, vein-quartz, and slates. Above this layer come more or less ferruginous sandstones, which are in places silicified, and these closely resemble the silicified rocks north of Strand Fontein. In Bamboe's Bay, three miles south of Strand Fontein, the ferruginous conglomerate passes upwards into sandstones, and these again into calcareous beach deposits with shells of species still living on the coast. The shell beds are hard grey sandy limestones with pebbles, but no sharp line marks the division between them and the underlying ferruginous sandstones. The maximum thickness of the limestone is 10 feet, and it is covered with sand. Further south than Bamboe's Bay the rocks underlying the superficial deposits make small outcrops only, and the dune sand conceals any other rocks that may lie between the old rocks and the surface.

The boulder beds and shelly limestones are certainly old beach deposits formed at a time when the level of the sea stood about 100 feet higher relatively to that of the land than is now the case. The sands and quartzites north of Strand Fontein probably belong to a somewhat later period, for they lie at a lower level than the beach deposits mentioned above, and fill up a depression that may have been cut out of the material deposited contemporaneously with the higher beach deposits. The sands north of Strand Fontein contain no marine shells, but seem to have been formed just behind the beach as sand dunes or in shallow pans, such as we see along parts of the present coast.

Perhaps the most interesting question in connection with these raised beaches is the origin of the granite and other pebbles, for no rocks of this nature exist in the neighbourhood so far as we know. It is very improbable that granite *in situ* occurs within a distance of 50 miles of Strand Fontein; the Bushmanland granite lies further north than that. From the general nature of the rocks forming these pebbles, and those which occur on the present beach near Strand Fontein, one would expect to find an outcrop of the Dwyka Conglomerate near by. The beach near Strand Fontein has pebbles of even a wider range of varieties than the raised beach. To the rocks named above, diabase, banded jasper, and amygdaloidal lavas of the Zeekoe Baard type must be added from the modern beach. These foreign pebbles were not seen on the beach south of Bamboes Bay or north of a point three miles north of Strand Fontein. The boulders bore such a close resemblance to those in the Dwyka Conglomerate that I fully expected to find an outcrop of that rock not far from the coast, but I did not come across it. It is possible there may be an outlier of the

Dwyka buried under the sand of the Sand Veld, and that the pebbles mentioned above were derived from it. The boulders are too large (often from 8 to 10 inches long) to have travelled far along the coast from the northwards; it should be noticed, also, that the current off this shore flows northwards, and in the accounts of Namaqualand we find no mention of amygdaloidal lavas or banded jaspers. The most probable source is an outlier of the Dwyka Conglomerate, now entirely removed by denudation or buried under the sand.

There is not much surface limestone in this district; it does not form hills or ridges, as in the Saldanha Bay area and on the coast of several of the southern Divisions of the Colony. A thin layer of whitish yellow limestone is met with in places near the coast and along the lower part of the Olifant's River just below the surface soil, but it does not reach a greater thickness than four inches. Where there is much dune-sand on the coast white limestone has been found at a depth of from two to three feet below the surface in the country behind, but it is not met with everywhere between the dunes and the inland limit of the Sand Veld. South of the Verloren Valley the white limestone has been struck at several places as far south as St. Helena Fontein, but the limited number of pits, which are the only means of getting information on this point, prevents an accurate idea of its distribution from being obtained. North of the Verloren Valley the white limestone is much less abundant, and appears to be generally confined to the immediate neighbourhood of the coast dunes. In the Harde Vlakte, a tract of rather low-lying country east of Donkin's Bay, there is less sand than usual, the soil is firmer, and there is a thin deposit of limestone just below the soil. The slighter development of limestone as the coast is followed northwards is probably due to the small rainfall in the northern part of the district.* The coast sand is not less calcareous in the north than in the south, but the water that percolates through the sand, and is therefore capable of removing the carbonate of lime in solution from one part of the sand and depositing it on evaporation, is certainly less in the north.

At many places in the Sand Veld there is a layer of ferruginous sandstone between the white sandstone and the underlying rock, or at a depth of from two to four feet below the surface of the sand. This rock is of the same nature as much of the "ironstone" of the Cape Flats, and is due to the cementation of the sand by hydrated oxides of iron. The ferruginous quartzites of the Van Rhyn's Dorp coast are similar in many respects, but do not contain the irregular cavities which characterise the other rock. This ironstone is practically identical with the laterite which will be described later, but it was partly formed at an earlier period. The cavernous laterite of the country south of Verloren Valley is probably still in process of formation by the deposit of iron oxides from water rising from the Malmesbury slates.

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* Rainfall at Ebenezer (near mouth of Oliphant's River) an average of 8 years, 4·64 inches; at Hopefield, an average of 3 years, 16·36. Ebenezer is in a district where there is little limestone, and there is very much near Hopefield.—Meteorological Commission, a Discussion of the Rainfall, etc., by A. Buchan. Cape Town, 1897.

(2). Surface-quartzites of the inland portions of the district. These rocks are distributed in a seemingly capricious manner over the whole area dealt with in this Report, excepting the Sand Veld, and even there it is not improbable that patches of it lie at the bottom of the sand. In the country between the Olifant's River Mountains and Piquetberg there are small outcrops, from 10 to 300 feet in diameter. On the exposed surfaces these rocks are intensely hard quartzites, with few cavities; below the surface the cavities become more numerous, and the silicious cement, to which the great hardness of the outer portion is due, is less abundant, and at the same time the amount of argillaceous and ferruginous matter increases. The cavities in the more siliceous rocks are often lined with minute quartz crystals. The lower part of the quartzite is often a breccia, owing to the presence of angular fragments of vein-quartz derived from the underlying slates by weathering *in situ*. On the right bank of the Berg Valley River on De Kruis there is a section showing the quartzite lying upon decomposed slates, and capped by some twenty feet of sand. The quartzite never extends very far laterally, the largest area of that rock in the district is on the left bank of the Olifant's River below Compagnie's Drift, where it covers parts of a river terrace about 150 feet above the present river bed; the area is two miles in length, and as it passes under sand and gravel it may be longer than that, but it cannot be more than three miles long. Its width is about half a mile, but a stream has cut through it and separated a portion on another part of the old terrace. In the Verloren Valley there are several small patches lying about 100 feet above the river, and others again on a lower terrace. In the Jakhal's Valley there are outcrops of the quartzite at about 20 feet above the river. In this valley the underlying rock is the Table Mountain Sandstone, some of the outcrops of which have a close resemblance to the surface quartzites when seen from a short distance. If the rocks be broken and carefully examined there is rarely any difficulty in distinguishing between them, owing to the peculiar nature of the cementing matter in the surface quartzites, which is often not purely siliceous, but contains very finely-divided clay or hydrated oxide of iron. No organic remains have been found in this rock in Piquetberg, Clanwilliam, or Van Rhyn's Dorp.

Though no important new facts concerning the surface-quartzites have been recorded from this district, the evidence of the formation of the rock on river-cut terraces, probably at a time when the rivers flowed at a higher level than they do now, is in accordance with the previous observations made in the southern coastal Divisions and between the Langebergen and Zwartebergen. The isolated, more or less circular patches of quartzite to the east of Piquetberg do not lie at much higher levels than the country near them, although they are usually found on the tops of the gentle undulations between the Piquetberg and Olifant's River Mountains. These quartzites do not form extensive sheets of rock, and from the manner in which they occur, often surrounded by level ground free from these rocks, it is clear that they were formed in small isolated areas, probably, as suggested by Kalkowsky,* by the action of organisms in vleys or swampy spots.

(3). We have already had occasion to mention some of the ironstone deposits found under the sand of the Sand Veld. Similar rocks are exposed at the surface, or occur immediately under the soil in the country east of Piquetberg Mountain. They consist of small lumps of sand or clayey matter cemented with hydrated ferric oxide; by the joining together of these concretionary masses irregular, more or less horizontal beds of a cavernous ironstone or laterite are produced; the inclination of the mass depends upon the slope of surface of the ground, but the beds are not formed on steep slopes, though the small nodules may be picked up on such hill sides. Whether these nodules are formed on the steep slopes or whether they have been washed down from the top of the hill is uncertain. The ironstone is a product of the weathering of the underlying slates, from which both the sandy, clayey, and ferruginous substances are derived. Small angular pieces of vein quartz are often met with in this rock, and occasionally water-worn pebbles brought from a distance.

(4) The alluvial deposits, silt and gravel, are naturally more abundant near the large rivers than elsewhere. The high-level gravels which form such striking features in other districts are but slightly developed in this area. Along the Olifant's River on the left bank there are terraces covered with gravel about 150 feet above the present level of the river, and these gravels are closely connected with the surface quartzites noticed on a previous page. The Olifant's River alluvial silt forms wide terraces, on the left bank below Nouwkous (Aan de Olifant's Rivier), and is the most fertile land in the district when irrigated. At the present time a few centrifugal pumps worked by steam or oil engines are used to take water from the river, and the

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* E. Kalkowsky, Die Verkieselung der gesteine in die nördlichen Kalahari Abh. d. naturwissenschaftlichen Gesellschaft "Isis" in Dresden. 1901.

results certainly warrant the extension of such enterprise. This alluvium is chiefly composed of fine silt brought down by the Tanqua and Doorn Rivers from the country east of the Cederberg range. The main stream of the Olifant's River, which rises under Great Winterhoek, brings down a comparatively small quantity of detritus, and its silt must be less valuable than that from the Karroo below the Roggeveld. The thickness of the alluvium is considerable, it must be more than 20 feet at many places, but I was unable to get exact figures for a maximum estimate. Within the alluvium and at a distance of a few inches from the surface there are nodular deposits of an impure white limestone, at places penetrated by irregularly disposed tubular cavities, which give the rock a close resemblance to the termites' nests and are analogous to the cavities in the ironstones; at other places the limestone deposit is identical in character with those formed under the reddish soil in the Harde Vlakte. These limestones are similar to the Indian Kankar. They are formed by the deposition of carbonate of lime in the soil from percolating water on evaporation.

In the Veloren Valley there is much silt, sand, and clay deposited by the river. The clay makes extremely good hard bricks, as may be seen in some buildings at Witte Drift, which have been built some years and are not covered with plaster, as is usually the case with buildings built of brick in the Western districts; the bricks appear as hard and well shaped as they ever were.

The Berg River near the south end of the Piquetberg range has a well-defined gravel terrace on its right bank, about 50 feet above its present bed. Below this neighbourhood the Berg River is bordered by wide alluvial flats partially covered with sand, but this portion of the district has not yet been surveyed.

(5). We have already had occasion to mention the pans behind the coast dunes, but there are other pans containing salt water situated far from the sea. In the Van Rhyn's Dorp Division there are two pans, one at Klip Fontein's Berg and the other at Heeren Logement. The Klip Fontein's Berg pan is at the western base of the mountain of that name. The pan is nearly a mile long and on the western side the ground rises to the Sand Veld. A peculiarity of the deposits formed in this place is the abundance of sulphate of lime, gypsum, which appears to underlie the sandy mud now deposited in the pan. On the north and east banks sections 15 feet thick through layers of granular imperfect crystals of gypsum are exposed. The gypsum is mixed with fine sand and carbonate of lime. Where the proportion of sandy mud increases the gypsum forms larger crystals than elsewhere. Lying upon the mud at the bottom of the pan is a thin layer of common salt, which becomes thick in the ditches dug for the purpose of allowing the salt water to collect. The origin of the gypsum and salt is by no means easy to discover. The rocks below the sand to the west are almost certainly Table Mountain Sandstone, which also forms the hills to the east. This rock contains neither salt nor lime compounds in any quantity; it is, considering its thickness, as siliceous a rock as can be found, and cannot have yielded any but an infinitesimal proportion of the soluble salts now found in the pan. The drainage area of the pan is quite small, and is chiefly in the Sand Veld, so it must be from the Sand Veld that the salts are derived. They are concentrated in the pan because there is no outflow from it to a river or the sea. A very similarly situated pan lies between the Heeren Logement and Klip Fontein's Berg, but gypsum is not present in sufficient quantity to be noticeable to the naked eye.

(6). The greater part of the shore of the district dealt with in this Report is formed by white shelly sand. Along the coast near St. Helena Fontein there are occasional layers of pebbles of black and grey quartzose slates, probably derived from the rocks underlying the Sand Veld, which are very rarely exposed. At Cape Deseada or Baboon Point, where the Table Mountain Sandstone crops out, there are many boulders of that rock on the beach and upon the wave-cut terrace that slopes upwards to the foot of the almost vertical cliff below Rheebok's Plaats, which lies some 300 yards from the sea. From Baboon Point to Bamboe's Bay there are no pebbles derived from any other rock than the Table Mountain Sandstone, with the exception of the pumice thrown up by the sea. From Bamboe's Bay to a point three miles north of Strand Fontein there occur the boulders of granite and other rocks foreign to the district that come from the raised beach previously described. In the neighbourhood of Strand Fontein there is a curious black sand on the beach. This sand consists of well-rounded grains of magnetite, zircon (in abraded crystals, now cylindrical in shape), and red garnet mingled with the usual quartz sand. It is difficult to assign the reason of its occurrence at this spot, for there are no rocks in the neighbourhood which contain these minerals in any quantity. At Bamboe's Bay the heavy grey limestone of the raised beach owes its grey colour and great density to the quantity of these minerals present, so there is little doubt as to the immediate source of the foreign sand, but this leaves the question of the original source unanswered.

The abundance of grey pumice with sanidine crystals along this coast is striking. Similar rocks are to be found along the southern and south-eastern coasts of the Colony, and from inquiries from lighthouse keepers who have been on the coast many years, it seems that the pumice was washed ashore after the Krakatoa eruption.

GEOLOGICAL SURVEY

OF THE

DIVISIONS OF ELLIOT AND XALANGA,

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The following Report deals with the geology of the Divisions of Elliot and Xalanga, areas which prior to 1894 were united in the single Division of Xalanga. The rocks met with include a small thickness of beds classed provisionally with the Beaufort Series, the entire thickness of the Stormberg Series, with its accompanying volcanoes and volcanic rocks, and in addition a vast quantity of dolerite in dykes and sheets penetrating the sedimentary strata. The geological lines could be laid down with considerable accuracy, owing to the large scale of the divisional maps (about one inch to the mile) and their general reliability, in marked contrast to those of the country north-west of the Drakensberg Range.

The area examined is bounded on the west by the Indwe River and by the high ground running from near Indwe to Waschbank Peak. The northern boundary is formed by the lofty Drakensberg Range, which usually rises from 2,500 to 3,000 feet above the ground at its base. From the Tembu Pass the boundary runs south-eastwards along a spur of the Drakensberg across the Gatberg, and then along the high ground east of the Gubenxa district, a ridge whose extension into Engcobo is known as the Matiwana mountains. The southern boundary takes advantage of the high ground to the south of Gubenxa, crosses the deep gorges of the Xuka and Umgwali Rivers, reaches Umtinthloni mountain near Cala, and then turns southwards parallel to the Tsomo River. The high ground building up the Umtingwevu mountains separates the Tsomo from the Indwe River, and at the same time divides Xalanga from St. Mark's.

The Drakensberg forms the highest part of the district, being usually between 7,000 and 8,000 feet above sea-level; from the base of the mountain the general surface of the country rises towards the south, and the rivers which rise in the Drakensberg have had, in consequence, to cut deep gorges. The best example is that of the Xuka River, which at the Engcobo boundary flows at a depth of 1,500 feet below the general surface of the ground on either side. The principal rivers are the Tsomo River in the west, with its tributaries the Xentu, 'Mbokotwa, and Entungela streams, the Slang and Xuka Rivers in the centre, uniting on the Engcobo boundary; while in the extreme east, Gubenxa is drained by the head-waters of the Bashee River.

There are several tracts of high country in Xalanga, for example, the ridge between Xalanga and Engcobo, culminating in Umtinthloni and Kwenkwezie (5,700 feet); also the Umtingwevu mountains (5,500 feet), between Cala, Askeaton, and Southeyville.

Although there is a considerable amount of traffic between Elliot and Barkly East, yet there is only one wagon road, namely, that known as the Barkly Pass, whose summit is about 6,700 feet above sea level. The Tembu Pass, a few miles to the east, rises to the same altitude, but there is only a bridle path over it. Between the Barkly Pass and Waschbank peak there are only a few bridle paths, *e.g.*, on the west side of Tafelberg and on Radobil. Wagons are occasionally taken up the latter, but owing to the steepness, it is but seldom used; a road was surveyed here some time ago, but as yet the work has not been begun.

The whole country is covered with grass in the summertime, but the Molteno sandstones and shales give rise to a very poor quality of soil, and it is chiefly where doleritic intrusions crop out that the vegetation really flourishes. The decomposed dolerite gives rise to a bright red soil, which is most frequently met with in valleys, and appears to be very fertile. Small isolated patches of forest are met with in the kloofs of the Drakensberg, especially towards the north-east. In the Xuka and Umgwali valleys similar forests are met with, the northerly extension of those of the Engcobo division.

The division of Elliot is cut up into farms, which are occupied principally by Dutch farmers; some of the larger areas have been sub-divided into small erven, the best example being the 'Mbokotwa Commonage, a little to the east of the Indwe River. Xalanga, on the other hand, is occupied chiefly by natives, but the ground has not yet been cut up into plots, such as has been done in Glen Grey.

The geology of the district is simple, for we have in Xalanga and Elliot the same beds which Mr. Dunn described in the Stormberg[*] and Mr. Schwarz in Matatiele[†], in descending order:

Stormberg Series	Volcanic Beds. Cave Sandstone. Red Beds. Molteno Beds or Coal Measures (Dunn)
Beaufort Series.	

The strata are either horizontal or inclined at a low angle, except where disturbed by doleritic intrusions. One monoclinal fold was observed on the east side of 'Mbokotwa Commonage, trending north-east with a maximum dip of 25°, but not extending for more than six miles. In the north the dip is generally towards the north or north-east; around Cala and in the west of Gubenxa the beds are horizontal, while in the south of the Divisions of Xalanga and Elliot the dip is towards the south and south-east.

There is a very gentle syncline along the valley of the Xuka River, whose origin may perhaps be connected with the occurrence of a vast lenticular intrusion of dolerite between the Slang and Xuka Rivers. The Beaufort Beds in this district are found in the valley of the Tsomo, from Cala southwards to the St. Mark's boundary; in the Indwe valley, from Indwe past Askeaton to Southeyville, and up the Indwana River for several miles north-eastwards from Askeaton. The red and higher beds are practically confined to the Drakensberg and its spurs; one notable outlier of the former, however, occurs on Umtwazwa (Los Kop), six miles to the west of the town of Elliot. The remainder of the country is occupied by the Molteno Beds, sandstones with shales, and occasional coal seams.

Plant remains are abundant in the Molteno Beds; those from the Stormberg and from Matatiele have been described by Mr. Seward,[*] and his classification has been followed in naming those from this part of the country.

THE BEAUFORT BEDS.

In the Stormberg area, Mr. Dunn found that below the "Coal Measures" there occur bright coloured clays and mudstones, with white sandstone bands, which he classed with the Upper

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[*] Dunn. Report on the Stormberg Coal Fields. Cape Town, 1878.

[†] Schwarz. Annual Report of the Geological Commission. 1903. pp. 13 *et seq.*

[*] Annals of the South African Museum. Vol. IV., Part I. Cape Town. 1903.

Karroo (Beaufort) Beds. In Xalanga they appear in the same position. For the sake of convenience, however, these coloured rocks have been separated from the upper beds, and provisionally classed with the Beaufort Series, until a more definite divisional line can be made out.

In the Tsomo valley, near Cala, several hundred feet of these beds are exposed, and they can be well seen at several of the bends of the river, and also on the west side of Commissioner's Kop, just outside the town. The harder beds consist of fine-grained, massive sandstones, usually yellowish in colour, though often bleached to a brilliant white; these beds of sandstone are always thinner than the beds of shale and mudstone, thus differing in character from the sandstones in the overlying Molteno Beds. The softer beds consist of dark purple mudstones, commonly sandy and seldom shaly for any distance. The lateral passage of laminated purple shales through mudstones into nodular sandstones takes place within a short distance. The mudstones contain dark purple nodules and grey pinkish fine-grained sandstone concretions, apparently containing very little carbonate of lime; the rock is usually mottled and spotted, and contains mica in minute white silvery scales. With these purple rocks there occur harder olive-green to pale yellow-green shaly mudstones, sometimes taking on a bluish tinge.

A few indefinite stems occur in the sandstones, while worm burrows are not uncommon. I am told by Mr. Black, of Cala, that during the construction of the Tsomo Bridge at Cala, the fossil remains of a reptile, about 10 feet long, with very large and long skull, were exposed in a small quarry on the west bank of the river. Unfortunately this fine specimen was destroyed, and no portion of it has been preserved. In sinking a well in Cala fossil bones were met with, partly embedded in and associated with yellowish brown highly calcareous nodules. Bones are also stated to occur in similar beds in the vicinity of the town of Engcobo.

The division between the red and purple beds and those classed with the Molteno group is usually quite sharp, but occasionally red or purple bands occur near the base of the latter. They differ, however, from those just described, in being very thin and containing abundant plant remains, chiefly striated stem or leaf fragments. A good occurrence is at a small quarry along the main road, about two and a quarter miles north of Cala.

THE MOLTENO BEDS.

These can be separated into several lesser divisions, whose characters are well marked throughout the greater part of this area. The following are the principal divisions in tabular form, with average thickness of certain groups of beds:—

Thickness in feet.	
400-500	9. White to yellow sandstones, with dark mudstones and occasional thin purple bands.
	8. "Glittering" sandstones, with bands of dark mudstone and shale and occasionally thin coals.
550	7. Gubenxa sandstone.
	6. Fine-grained sandstones, with silicified wood.
	5. Coal horizon. (Newcastle and Cala Pass coals.)
	4. Soft, fine-grained sandstones, with mudstones.
600-700*	3. Indwe sandstone, with ironstone nodule band, and underlying fine-grained sandstones.
	2. Coal horizon. (Indwe and Cala coals.)
	1. Fine-grained felspathic sandstones, with dark shales and mudstones.

From this table it is seen that the maximum thickness of the Molteno Beds in this district is 1,900 feet, and they appear to get thinner towards the west. I have not yet had an opportunity of measuring their thickness at Indwe, but Dunn has given it in that locality as 1,000 feet.† In Matatiele, almost 100 miles to the north-east, the Molteno Beds have been roughly estimated at 2,000 feet, though their base is not certainly seen.

(1.) The basement beds of the Molteno group consist of massive, soft yellowish-white felspathic sandstones (not distinguishable from those of the underlying Beaufort Beds) and shaly sandstones and mudstones usually of a dark bluish or blackish colour, or when bleached, of a pale blue or buff.

Fine exposures of these beds are seen in the road cuttings up the Cala Pass, a continuous section of about 250 feet of beds being laid bare. What is most noticeable is the great amount of sandstone, the shales and mudstones being quite subordinate, though on the hillsides this fact is not apparent. This is to a great extent due to the rapid weathering of some of the soft felspathic sandstones, which then resemble shales. False and irregular bedding in the sandstones and local unconformities are frequent, as are also lenticular patches and strings of black shale and coaly material. Clay pellet and ironstone conglomerate occur in irregular bands and lenticles, and occasionally a pebble or boulder of white quartzite, such as are found in the conglomerate above the Molteno coals. Some of the sandstones contain concretions like small cannon balls, usually from two to three inches in diameter; they are ferruginous and darker in colour than their matrix, and owe their origin in many cases to the oxidation of iron pyrites.

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* Since this was written a *Thinnfeldia* has been found 150 feet below the base of this section, but not lower down.

† Report upon recent coal-borings in the Camdeboo and Stormberg. 1883. p. 8.

About 250 feet below the Indwe Sandstone there occurs a pale bluish sandstone with large concretions, often many feet in length, of hard dark sandstone, weathering to a brownish purple colour. These are well seen in the bed of the Cala River, on the farm Kohli, to the west of Cala.

About half-way up the Cala Pass, and about 200 feet below the Indwe Sandstone, there occurs a band of impure coal, from two to three inches in thickness, with which are associated shales and mudstones, with abundant fossil plants, *e.g.*, *Thinnfeldia odontopteroides*, *T. rhomboidalis*, *Taeniopteris carruthersi Baiera sp.*, *Phoenicopsis elongata*, and *Schizoneura krasseri.* Plant remains are very common in the shales of division (1), as, for example, at a prospecting shaft on the Cala River, on the farm Kohli, where the shales and shaly fireclay contain abundant iron pyrites, often collected round the plant remains. These beds have yielded the above-mentioned forms, and in addition *Stenopteris elongata* and *Callipteridium stormbergense.* The shale beds throughout Xalanga are, however, seldom exposed, owing to fallen debris, and hence there are but few localities where well-preserved plant remains can be obtained without difficulty. Just below the Indwe coal horizon there occurs a thick bank of fine-grained felspathic sandstone, close on one hundred feet thick and fairly well bedded. A little above this comes the Indwe coal and Indwe sandstone. The latter has characters that enable it to be easily recognised at a considerable distance; it usually forms a prominent krantz at the edge of a tableland, and is slightly reddish in colour, with rough vertical jointing. Immediately below it come paler, well-bedded sandstones. The coarse pebbly Indwe sandstone does not, as a rule, break up into big rectangular blocks as the higher beds of coarse "glittering" sandstone do, but an exception to this occurs at Rebels' Kloof, about seven miles west of Cala. Its ability to resist weathering, which causes it to form lofty flat-topped hills, is in part due to the fact that over a considerable part of this area it has been directly overlain by a thick sheet of intrusive dolerite, as on the hills round about Cala and Askeaton, in the Umtingwevu mountains, in the Slang, Xuka, and Umgwali valleys. Hence it is, that where coal is found below the Indwe sandstone, it is almost always semi-anthracitic in character—even Indwe itself has not escaped, though the alteration in the coal there is but slight.

The Indwe sandstone can be followed southwards from Indwe, down the left bank of the Indwe River, *e.g.*, at Lupapasi, Landula, in the Indwana River basin, from Askeaton to Southeyville, and then eastwards along the flanks of the Umtingwevu mountains into the valley of the Tsomo River; then further on both sides of the Lafuta River, the Exme stream, Cala River, Tsomo River from Cala as far as the Elliot boundary (Tillitudlem) and all along the boundary range on the east of Xalanga Division. Towards the north and north-east it passes beneath higher beds. In the south of Elliot and north of Engcobo the Indwe sandstone forms prominent krantzes, for example in the Umtinthloni mountain and the Umgwali River valley, while along the Blaauw Valley, Slang and Xuka Rivers, it can be seen forming a krantz very low down, at first right in the beds of the rivers, but rising towards the south, until it again forms a cliff facing the high ground which overlooks the town of Engcobo.

To the north and north-east it is covered up by higher strata and by the dolerite of the Slang River.

Before describing the lithological characters of the Indwe sandstone, it would be as well to mention the occurrences of coal below it. Although there are many miles of outcrop of the Indwe sandstone throughout this area, yet the hillsides are so covered with debris from the cliff above that there are rarely any natural exposures by which the presence or absence of the coal may be determined. Consequently there has been but little prospecting done, and artificial openings are usually far apart and never on any systematic plan; it is impossible to judge of the extent of the coal from merely one or two cross-cuts. Sometimes a seam thins out rapidly, so that within a couple of hundred yards we may have only a solid bed of sandstone, with no trace of the coal; such is the case with an outcrop a little south-east of Zadungeni, which is mentioned in detail later on. At other places transport difficulties are such as to preclude any hope of successful working of coal, even should the seam prove to be thick, continuous, and of good quality. In many localities, again, the strata are so riddled with dolerite in vast dykes and sheets that to prospect for coal would be merely futile.

A thin coal seam occurs above the farmhouse of Landula (Xalanga Division), about 600 feet above the Indwe River, and as the purple mudstones occur in the river bed just at the drift, we have here about 550 feet of Molteno Beds between the Beaufort Beds and the Indwe coal, or 600 feet up to the Indwe sandstone. At Indwe itself, from a surveyed section taken by the Indwe Company, the distance from the Beaufort Beds up to the Indwe sandstone is 450 feet, so that the Molteno Beds appear to thicken somewhat towards the south-east. Just west of Cala fully 730 feet of strata intervene, and still farther east, close to Umgwalana Nek, the thickness appears to be even greater. It would be interesting to know whether the beds still continue to thicken when followed to the south-east into the Engcobo Division.

A thin coal seam occurs right in the extreme south-east corner of the Xalanga Division, above the Mahlungulu River, and about a mile from the trading station of Nyelasa.

A little to the west of Cala, in the angle made by the junction of the Cala and Tsomo Rivers, there is a tableland rising over 900 feet above the rivers, with Beaufort Beds visible at its base and Indwe sandstone at its summit. Beneath the krantz, on its south side, there is an outcrop of coal, which is being at present developed by Mr. Hammond, of Cala. A drive has been put in to a distance of about sixty feet, and the coal has also been proved at several points towards the west. A section near the coal face is as follows:—

Dark grey sandstone, with thin lenticles of coal ...	roof.
Black shale	4 inches.
Coal	12 „
Black Shale	2 „
Coal	8 „
Shale	5 „
Coal (impure)	3 „
Sandstone	floor.

The seam dies out at about 100 feet east and also at about 480 feet towards the west, but occurs again farther on at several points. More work will be necessary to determine the area of workable coal. It is of good quality, and is semi-anthracitic in character. The following analysis was made by Mr. J. G. Rose, of the Government Analytical Laboratory:—

Moisture	1·50 per cent.
Ash	19·70 „
Volatile matter	9·50 „
Fixed carbon	68·51 „
Sulphur	·79 „

It therefore resembles very closely the Stormberg and Indwe coals, but contains a slightly lower proportion of ash.

The plateau below which the coal occurs is bounded on the north and west by huge dolerite dykes, which have been intruded along lines of faulting. A sheet of dolerite must formerly have spread over the plateau, and thus baked the coal. Part of the dolerite still remains capping the Indwe sandstone about a mile and a half towards the north. Both the floor and the roof of the coal seam are of sandstone, with very irregular surfaces, and are occasionally in the form of sharp ridges. The sandstone contains numerous soft bands of coaly laminae and occasionally patches of fireclay. Carbonised plant stems are abundant, and occasionally there are rounded white quartzite pebbles.

Adits exposing thin coals occur below the Indwe sandstone in the south of the Elliot Division on the farms Umgwalana Nek and Aultbea.

On the farm Craignish, below the Indwe sandstone on the right bank of a small stream running into the Xuka River, the coal has been opened out by means of two headings close together. Both floor and roof are of sandstone, the latter undulating and containing occasional quartzite boulders. The working height of coal and shale is not more than three feet, the coal being confined to the uppermost portion. The seam appears to be somewhat irregular, as patches and lenticles of shale occur in the coal, and it would therefore require careful screening, the total available thickness being probably not much over one foot. The coal is well laminated, but often compact, with a pseudo-crystalline appearance. It varies from a semi-anthracite to an anthracite, this being probably due to the former presence of a large overlying dolerite sheet, portions of which are seen on the adjoining farms Lora and Peninsula.

The same seam is visible in cliff sections on the Xuka River a little further along, on the farm Koning's Kroon. It is questionable whether this coal will be worth working, as the country is very rough and the roads very heavy, the town of Elliot being over twenty miles away.

Two occurrences of coal are met with just south of the Elliot boundary and immediately within the Engcobo Division, but they can be described here.

One of these is in a branch of the Xuka, about one mile south-east of Zadungeni.

In an adit the following section is exposed:—

Sandstone	roof.
Coal	12 inches.
Hard black shale	4 „
Coal	4 „
Shale, sandstone, etc.	

The coal is well laminated and rather hard, but burns well, with no very great flame, being more of the nature of a steam than a house coal. This is due to the influence of a great inclined sheet of dolerite a short distance to the west having a thickness of 300 feet, and dipping at a moderate angle towards the south-west. This coal extends towards the east and probably towards the west as well, but within one hundred yards on the north it thins out and disappears.

In the band of shale between the coal seams remains of *Callipteridium stormbergense* and a species of *Cladophlebis* were obtained.

The most important occurrence of coal, however, is that occurring on the banks of the Umgwali River, about three miles west of Zadungeni, the eastward extension of which has just been described. Whether the coal is worth working beneath Zadungeni itself is doubtful, as the thick dolerite sheet appears to cut right through the strata a little distance away. The coal has been opened out at a number of points close together below the krantz of Indwe sandstone, while the main drive has attained a length of about 300 feet. This coal is at present worked and transported to Cala, where it is utilised in the steam mill, and compares favourably with coal brought from Indwe. If the field is not traversed by dolerite towards the north, there should be a large amount of valuable mineral present, which, if the proposed railway from Engcobo to Elliot be ever built, could be utilised in Elliot, Engcobo, and places further to the south.

The sandstones above the coal horizon are pale greyish and felspathic, rather fine-grained, and somewhat well laminated; false-bedding is common, and they contain pebbles of white quartzite, sometimes along certain ferruginous layers, but commonly scattered irregularly and rather sparsely through the rock. These white quartzite pebbles are usually from 4 to 6 inches in length, but one of over 20 inches was noticed. Higher up—usually about 30 to 40 feet above the coal —occurs the ironstone nodule conglomerate or the "oyster-bed," as it is called at Indwe, a very constant and easily recognisable band. Other patches of this ochreous and haematitic conglomerate do occur in the sandstone just above the coal, but never well developed, and often only in pockets. In the sandstones there occur thin laminae and seams of coal, carbonised stems of trees, and occasionally stems replaced by iron oxide, but always of a very indefinite character. Immediately above the ironstone conglomerate comes coarse pebbly felspathic sandstone, usually somewhat pinkish in colour. The felspar is often extremely abundant, so that the rock resembles an arkose; the fragments may attain a size of about half an inch in length. The grains of quartz are usually clear and crystalline, but milky white and grey black fragments also occur—the grains are mostly rounded, and show secondary crystal growth.

Above the Indwe sandstone come again fine-grained felspathic sandstone, with mudstones identical with those lying below it, with a thickness of about 150 feet. Here then we have another horizon (5) at which coal is found. One of these localities is almost at the summit of the Cala Pass—about six miles north of Cala. Some years ago the coal here was opened out and worked, but only to a limited extent. The seam is described by Mr. Galloway in his report,* but another section is laid bare about 600 yards farther west in a ditch beside the main road to Elliot near the summit of the Pass.

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* Galloway. Report on the Coal Deposits of the Indwe Basin and Stormberg Range of Mountains, p. 10, sect. *a*. Cape Town, 1889.

Massive sandstone	roof.
Coal	12 inches.
Shale	4 „
Coal (impure at base)	7 „
Shale with thin impure coaly bands ... ... over	30 „

About 100 yards east of this there is a small quarry almost on the same level as the coal in which sandy mudstones occur with shales, and one thin coaly band with abundant plant remains, including *Thinnfeldia odontopteroides, Taeniopteris carruthersi, Baiera schenki,* and *Phœnicopsis elongata.* A little father up the hillside come black earthy shales with plant impressions, the upper six inches of shale being now converted into a grey flinty bed by an overlying four foot dolerite sill of small extent. On the farm Koning's Kroon on the east side of the Xuka River in the south of Elliot, and just behind the farmhouse, there occur several feet of black shale, with thin impure coal bands, in the same position with regard to the Indwe sandstone as the Cala Pass coal, but of no commercial value. Above the shale come about eight feet of mudstones and shales crowded with striated stems and with fern fragments; above those again a band of about ten or twelve inches of blue flinty shale, very hard, and weathering to a very pale whiteish blue. This is not an altered shale, although a sheet of dolerite does occur a little above it; it is quite an exceptional type of rock and contains abundant plant remains, very well preserved, including *Thinnfeldia odontopteroides, Taeniopteris carruthersi, Callipteridium stormbergense, Schizoneura krasseri,* and probably *Baiera stormbergensis.* Higher up—about 400 to 500 feet—occurs:—

(7) The Gubenxa sandstone, which caps the mountain range, a bed which can be traced without difficulty north-eastwards through Sundwana (Tomar) into the Gubenxa district.

The sandstone forms a marked feature in that tract east of the Xuka River, just as the Indwe sandstone is so prominent to the west, and they resemble one another to a very great degree.

The Government coal reserves in the Gubenxa districts, consisting of the two farms Tafelberg and Newcastle, are traversed by the two branches of the Gcaga stream. On the northern farm, Tafelberg, right in the bed of the river, black shales with coaly bands crop out at intervals; owing to erosion by the stream, in none of the sections is the upper portion of the seam present. Unfortunately, there is a broad dyke of dolerite cutting across the river bed and giving rise to a sheet, which is intruded right in the midst of the coaly material and black shale.

The sheet varies from a few inches up to four feet, where visible, and has rendered the coal in contact with it valueless.

On the southern farm, Newcastle, the coal also crops out in the bed of the river, the section having been described in Mr. Galloway's Report*; the total thickness of coal being 22 inches, with fireclay underlying the seam. The coal has been baked by a sheet of dolerite about 30 feet thick, which has been intruded a little above the level of the coal, and which crops out for a couple of miles on either side of the Gcaga stream. If this sheet is the underground extension of that seen on Tafelberg, as is very probable, then it is most likely that much of the coal will be coked, and in places even "blind." Consequently the value of the Government Reserve may be a great deal less than has been estimated.

The coal is found again a little higher up the Gcaga stream, just outside the Newcastle boundary, and here the dolerite appears to be absent.

To the south-west of Newcastle, below beacon No. 35, on the Engcobo boundary, a mile south of the Gubenxa stream, there is an exposure of six feet of black shale, with a 10-inch seam of coal near the top. There is a sheet of dolerite crowning the hill, but the seam is too far below to be affected by it. This seam is probably at the same horizon as that seen on Newcastle, but it may possible be a little higher up in the series. Another seam of coal about 12 inches thick, but rather impure in character, occurs about 80 feet below the first one. Other thin seams occur at various places in the district, but, as far as I saw, are never of any importance.

The Gubenxa sandstone is very prominent throughout the Gubenxa district, but west of the Xuka River it becomes almost identical with the numerous "glittering" sandstones of the upper portion of the Molteno Beds; for example, just on the west of the Tsomo River, on the farms Turva and Tillitudlem. On the latter farm, along the main road from Elliot to Indwe, there is an outcrop of a very peculiar rock just below the beacon called Mazeppa. This is a bed, apparently of small extent, and not more than three feet thick, which has weathered in a pile of blocks strewing the hillside. It is composed of a fine-grained pinkish cherty quartzite passing into a dark blue-black rock in places, and it contains abundant fragments of silicified wood, occasionally becoming quite like a breccia.

The sandstones with silicified wood are well seen on the summit of the Cala Pass, near Navar, at Cluny (opposite to Tillitudlem, but on the east bank of the Tsomo), and on the ridge between Rebels' Kloof and Garry Owen on the Cala-Indwe road.

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* Report upon the Coal Deposits in the Indwe Basin and Stormberg Range of Mountains, 1889, p. 10.

This horizon between the second coal and the Gubenxa sandstone is the only one at which silicified wood was found in any quantity, and it always occurs here embedded in a soft yellowish felspathic sandstone, with beds of hard mudstone.

The beds of the Molteno group above the Gubenxa sandstone consist of pebbly glittering sandstones (often highly felspathic), with soft mudstones and shales, the former forming krantzes, from which numerous rectangular blocks break off and strew the hillsides. The softer beds are consequently rarely exposed and opportunities for collecting plant remains are infrequent. On the farm Berriegoniam, near the foot of the Barkly Pass, a borehole for water was put down alongside of a dolerite dyke, and passed through one of these sandstones. A sample of the core when assayed is stated to have given several pennyweights of gold to the ton. Many of these sandstones are conglomeratic, with quartz pebbles reaching up to an inch in diameter; such beds are commonly called "banket" by the Dutch farmers, and believed by them to be auriferous. The highest of all the coal seams noticed in the Molteno Beds occurs on the farm Offa, to the north-west of Elliot and close to the Tsomo River.

Two headings have been driven into the hillside and a quantity of coal extracted, but the mine at present remains unworked. The coal is not of very good quality, containing a large amount of shaly material, and requiring careful hand-picking. Other outcrops of coal, probably on the same horizon, are met with some miles farther west, at the north of the farm Ordfianna, on the Tsomo River, and at the farm Coulterburn, on the bank of the Vaalhoek stream.

The very topmost beds of the Molteno group are characterised by the disappearance of the coarse glittering sandstones and their replacement by finer and more felspathic beds. At Ordfianna such a bank of sandstone outcrops, and is interesting, as, in addition to numerous indeterminate plant stems, it contains many well-preserved fronds of *Thinnfeldia odontopteroides*, this being the highest horizon at which this fern was noticed. A portion of the sandstone also contained large rounded quartzite pebbles, usually collected together, and not distributed uniformly through the rock. The shales are hard and dark blue, but purplish bands begin to appear, and in a short distance we pass into the higher group of the Red Beds.

THE RED BEDS AND CAVE SANDSTONE.

Both of these divisions of the Stormberg Series are finely developed in the Elliot Division; their total thickness varies from 1,800 to 2,200 feet.

The Red Beds form the lower slopes of the Drakensberg and build up the spurs in the north-eastern part of Elliot, while a prominent outlier is Umtwazwa or Los Kop, six miles west of the town of Elliot. The Red Beds have been so called owing to the occurrence in them of red and purple sandstones, mudstones, and clays, by which they are distinguished from the Molteno Beds. Another distinguishing feature is that while the latter have banks of "defining" sandstone spaced at regular intervals, the former are characterised by bands of finer grained sandstone distributed irregularly. The outlines of the hills are in consequence smoother and more rounded, while the colour is much darker, except where obscured by grass. Organic remains are almost entirely absent from the upper division of the Stormberg Beds; nothing was noticed in the Cave Sandstone, and although the Red Beds were carefully examined at a number of points, the only place where reptilian remains occurred was on the farm Knapdale, north-east of 'Mbokotwa Commonage. The bones were fragmentary, though belonging to some large form, and were embedded in a hard purple calcareous mudstone, the horizon being a few hundred feet above the summit of the Molteno Beds. No plant remains were obtained in them anywhere, though *Thinnfeldia odontopteroides* occurs on Ordfianna at the top of the Molteno Beds. Silicified wood occurs embedded in quartzite at the peculiar volcanic neck No. XII.

The base of the Red Beds is usually well enough defined, but at several points, *e.g.*, on the east of 'Mbokotwa Commonage, where the rocks must certainly belong to the Red Beds, none of the purple mudstones are visible; this, as will be seen later, is probably due to bleaching of the strata. At Xuka Drift and near Maxongo's Hoek there is a large amount of buff and blue mudstone and shale, with an occasional red or purple band, and with much yellow sandstone. Here red and purple beds do not predominate, but as no similar rocks are met with lower down, the base of the Red Beds has been drawn at the bottom of the lowest purple mudstone band. This lithological division appears satisfactory, for when followed from east to west the Red Beds, thus separated, have a nearly constant thickness.

The colours of the soft bands in the Red Beds are often very brilliant; red, purple, green, and white mudstones are abundant, while in a road quarry on the north-west corner of Maxongo's Hoek Commonage sandstones and mudstones occur of a very peculiar and beautiful soft violet colour.

Sandstone banks are abundant in the Red Beds, often up to 30 feet in thickness, and are usually of a yellow colour; many of the beds, however, were originally red or purple, and have had their colouring matter removed. Thus, on the farm Water Kloof, a few miles north-east of Elliot, there are many places in the steep ravines where freshly-exposed surfaces of the sandstones are met with; the original bright red colour of the beds is then visible, though some distance off on the hillside the same sandstones exhibit pale yellow surfaces when fractured. The same is the case, only less commonly, with the shales and mudstones; thus beds which are yellow on the weathered surface are, when unweathered, dark bluish-green, and others, which are pinkish or mauve outside, are red or deep violet in the unweathered state.

As a rule, the commencement of the Red Beds is indicated by the disappearance of the coarse "glittering" felspathic sandstones so characteristic of the upper Molteno Beds, their place being taken by others which are finer grained. Only occasionally are bands of coarse sandstone met with in the Red Beds, and they appear to have only a local development. Conglomerate beds are, as a rule, absent, but a notable exception occurs on the south-east corner of Struman, where a bed of sandstone contains abundant white quartzite and quartz pebbles, which readily weather out and cover the surface of the ground. At several other localities a few boulders of quartzite were seen lying loose on the surface soil.

The upper limit of the Red Beds is usually somewhat indefinite, owing to the great development of thick sandstone beds just near the base of the Cave Sandstone. In several places the latter is of a brilliant red colour at the base, as on Water Kloof, and the defining line is quite sharp; yet a short distance away these red beds are bleached to a yellow colour, and are indistinguishable from the overlying Cave Sandstone. At other places the Cave Sandstone rests upon thin-bedded sandstones and shales, and then the divisional line is quite distinct. It is rather difficult, in consequence, to draw a very sharp line dividing the two sets of rocks; the process of sedimentation was continuous, and there is often a gradual passage from the one into the other.

The Cave Sandstone is a massive bed of yellowish fine-grained felspathic sandstone, of remarkable uniformity of texture when its great thickness in considered. As a rule, it is slightly stratified at its base, but more so at its summit. Lamination is usually absent, but in a few places, especially on the farm Ballater, below Tafelberg, there are fine sections, showing current-bedding on an extensive scale. The sandstone weathers very irregularly, portions of it are readily eroded and crumble to a yellowish sand, while other parts become harder, and project as lofty pinnacles and buttresses on the mountain sides. A beautiful example of this is seen to the north-east of Elliot village on the farm Waterkloof; the softer parts form rounded grass-covered slopes, from which project towers and pillars of hard yellow Cave Sandstone, some of which are over three hundred feet in height. The most fantastic forms are assumed by the sandstone; on the Gatberg a small outlier is pierced with a window-like opening; on Balclutha a mass resembles a turreted castle; while on Glenalvon there are long walls of sandstone, as much as half a mile in length, as if of masonry, rising vertically to a height of almost five hundred feet. From a distance the sandstone is usually pale whitish yellow, and this is commonly the colour of weathered surfaces, but pink and reddish tints are the colours of the rock when fresh. The sandstone is often full of minute yellow ferruginous spots, at other times of small concretions from the size of a pea up to two or three inches in diameter, usually of the same colour as the matrix that contains them. Sometimes the concretions are purple-red in yellow sandstone or *vice-versa*; the concretions either project above the surface or weather out and form holes. Very hard purplish quartzitic concretions of very irregular outline are common both in the base of the Cave Sandstone and summit of the Red Beds; in some cases they reach a length of several feet. Below the Tembu Pass the Cave Sandstone, which is pinkish, weathers spheroidally, just like some dolerite intrusions.

We may now proceed to a detailed description of the Red Beds and Cave Sandstone, commencing at the eastern end of Elliot.

Just north of Xuka Drift hotel there is a fine krantz of solid sandstone, representing the top of the Molteno Beds, and at the foot of which runs the new road to Ugie. The sandstone has a dip to the north; in the river bed on Sunart purplish and greenish mudstones are exposed, while higher beds are met with in a spur of Mount John Bull. There is here a great abundance of yellow sandstone and green and blue shales, while purple beds are but poorly represented. This is only at the foot of the mountain, for the upper part contains numerous beds of red and purple sandstones. The Red Beds extend along the Maclear boundary, and build up the Gatberg with its small capping of Cave Sandstone, and the ridges on the west of Noah's Ark Commonage.

The three volcanic necks, Nos. I-III., are found here in the Red Beds; they will be described later on, together with the peculiarities of the rocks surrounding them. At the head of the stream coming down from the north-west corner of the Commonage there is a thick pale bluish sandstone in the middle of the Red Beds, which is cut through by a peculiar dyke, about two feet wide; the latter runs obliquely across the face of the rock, and in appearance and weathering is similar to a dolerite dyke. It is, however, composed of a greenish-brown fine-grained sandstone, and has no igneous material in it. It encloses fragments of the surrounding sandstone, and has cavities filled with crystalline calcite; and at the contact with the walls it shows a fine compact dark selvage, usually about a quarter of an inch in thickness. It is probably due to the infilling of a fissure with heated mud, a view strengthened by its proximity to the volcanic neck No. III. The sandstone and hard splintery mudstone a few feet above the dyke have numerous cracks and joints filled with a soft white fibrous mineral that has been called asbestos; it occurs with its fibres at right angles to the enclosing walls, and on examination proves to be fibrous gypsum. A similar occurrence has been noted by Mr. Schwarz in Matatiele,* also in association with a dyke, but the mineral in that case consisted of carbonates of calcium and strontium. It might be noted here that about half-way up the Barkly Pass there is another fissure, about two feet broad, cutting almost vertically through the Red Beds, and filled with a mass of orange coloured sandstone, rather rotten and somewhat clayey in character.

The spur west of the commonage terminates southwards in the rounded mass called Mount Ararat of Pangela (6,212 feet), capped with a very thick massive sandstone, well seen on its western face, and which, being too low for the Cave Sandstone, must belong to the Red Beds. West of the commonage the high ground is cut into by several branches of the Xuka River, the Nqumeni and Maxongos streams and Little Jackal's Kop Spruit, which give rise to long valleys reaching as far as the Elliot boundary. These valleys are carved entirely in Red Beds, and beautiful sections are afforded on the river banks, where landslips have recently occurred, especially on the farms Nqabeni and Mountain Cliff. On the latter there is also a very fine section near the top of one of the ridges, where the frequent alternation of sandstones and mudstones (coloured purple, red, and occasionally dark blue) is well displayed, and the true red colour of the sandstones becomes plain. At the head of the valley a semi-circle of Cave Sandstone occurs, capped by the lavas of the Tembu Pass (see p. 195); the former, which is easily measurable, is found to be no less than 800 feet in thickness.

The Red Beds here have a thickness of 1,400 feet, a great difference when compared with the 200 feet they attain in Matatiele†; evidently both Cave Sandstone and Red Beds must thin considerably towards the north-east. The base of the Red Beds now runs south-west round the foot of the dome-shaped mountain, Basuto Cave, which, like Mount Ararat, has a massive sandstone at its summit. The line of outcrop winds about Palmiet Fontein, and then turns northwards, passing within a couple of miles to the east of the town of Elliot, till it reaches the farm Waterkloof.

This corner of Red Beds is traversed by a thick dyke of dolerite running from Palmiet Fontein to Waterkloof. From

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* Ann. Report Geol. Commission, 1902, p. 28.

† Ann. Report Geol. Commission, 1902 p. 27.

Basuto Cave to the Gatberg there run several dykes or inclined sheets of coarse-grained dolerite, which cross and interlace in a very irregular manner. On the farm Waterkloof it is most interesting to see a cliff-section showing the great dyke of dolerite cutting through the Red Beds diagonally, and gradually thinning as it rises. By the time it reaches the Cave Sandstone, it is not more than ten feet thick, and finally can be seen as a narrow dyke in the sandstone on the farms Scarba and Tulloch, appearing to reach as far as the edge of the great Tulloch Volcano. Here we have a very fine example of the manner in which the great intrusions of dolerite terminated upwards originally; as the fluid rock ascended, its penetrating power became less and less, and finally it was stopped through lack of a great enough pressure beneath it. This same dolerite intrusion evidently extends underground north-westwards from Waterkloof towards the Barkly Pass, for on the farms Corryvrechan and Malvinia it has been exposed where two rivers have sawn their way through the covering of Red Beds.

On Waterkloof, just above the farm-house, the following section occurs at the junction of the Red Beds and the Cave Sandstones:—

4. Yellow to pale bluish-green sandstone.
3. Purple to red sandstones, weathering spheroidally and containing quartzitic concretions.
2. Thin white sandstone, with pink quartzitic concretions.
1. Purple Shales.

All the rocks below 4 belong to the Red Beds.

By far the most interesting and accessible locality for studying the Red Beds is at the Barkly Pass, where for six miles, from the Tsomo River up to the Barkly East boundary, the road rises continuously and numerous cuttings have been made, Red Beds and Cave Sandstone being finely exposed. The former begin almost in the river bed, and consist of peculiar soft purple-black sandstones, shales, and mudstones, with a small quantity of light blue or bright yellow sandstone and sandy shales. Then comes a bed of massive yellow sandstone, resting upon an eroded surface of purple and grey laminated sandstone. Two more such massive sandstones, with beds of soft pink and purple beds in between occur, and then at about 400 feet from the base, a considerable thickness of dark blue-black mudstones and yellow sandstones are met with. These are succeeded again by laminated sandstones, massive yellow sandstones and purple and green mudstones for some five hundred feet.

It is very noticeable how often the massive sandstones lie upon an eroded surface of softer beds; they are irregular in thickness, sometimes lenticular, and occasionally they appear confused with the mudstones and tilted on edge, by an apparent tilting of the bedding planes, which is due really to false-bedding and irregularity of deposition, the beds above and below running quite evenly. At about 1,100 feet white sandstones appear, sometimes in beds 30 or 40 feet thick, and commonly close together, with interbedded soft purple sandstones and mudstones with peculiar hollows or cavities. Near the top of the series a very massive white sandstone is met with, probably the same that is seen capping Mount Ararat, and finally the bedded rocks pass into the Cave Sandstone. It is difficult to draw any precise boundary, as the Cave Sandstone at its base often contains thin layers and lenticles of pink and red sandstone and soft mudstone, and is often false-bedded. The great mass of the Cave Sandstone is fine-grained, pink in colour, sometimes reddish, as is well seen in the road cuttings on Barkly Pass Extension. The thickness of the Red Beds is fully 1,600 feet, while the Cave Sandstone cannot be far short of 800 feet; from this point the former maintain their thickness up to the Wodehouse boundary, while the latter gradually becomes thinner.

Just north-west of the Barkly Pass a dolerite dyke is seen cutting through the Cave Sandstone, and crossing the divisional boundary; another small dyke running east and west cuts through the same formation on Glenalvon, but does not appear to traverse the lavas above. It consists of fine-grained dolerite, compact and not vesicular, otherwise it might be regarded as a fissure from which some of the lavas issued.

A small outlier of Cave Sandstone occurs on Kilchamaig, next to Ballater, almost a mile south of the main outcrop of that formation. The junction with the underlying Red Beds is beautifully distinct, and on the west side the latter beds form a very steep slope, at the foot of which is the farm-house of Ballater. On the north-east side of the outlier there is a very peculiar mass of what seems to be Cave Sandstone, but which occurs on the hill side several hundred feet too low to be that rock. It does not appear to be a part of a landslip, and resembles more a volcanic neck plugged with sandstone; but there are no sharp boundaries, and no undoubted tuff is seen anywhere.

The Red Beds about here are traversed by a great sheet of dolerite (coarse-grained) dipping eastwards, and by a number of lesser dykes. Like the dyke on Waterkloof, the dolerite thins as it rises, and the outlier of Cave Sandstone on the ridge is cut through by a thin sheet.

The outlier of Red Beds which builds up the mass of Umtwazwa or Los Kop needs a little description. This hill forms a long ridge running from the Tsomo River, at Ordfianna, south-eastwards towards Navar; its south-west face is steep, but on the north-east it slopes away at a gentle angle. When examined from the south-west, the upper part of the ridge is seen to be composed of Red Beds, with a thick bank of yellow medium-grained sandstone separating them from the underlying Molteno Beds, with dark shales and "glittering" sandstones. A great sheet of very coarse-grained dolerite is met with all along the summit of this ridge, from Navar to Ordfianna, then crossing the Tsomo River and uniting with the dolerite described on Kilchamaig. This dolerite evidently displaces the beds, for on the north-east the Red Beds occur at a higher altitude, and consequently do not extend so far north-west and south-east as those on the south-west. To the west and south-west of Ballater the Red Beds cover a considerable extent of country, being cut into by numerous rivers, *e.g.*, Vaalhoek, Xentu, Qokama, Voyizana, Entungela streams and the 'Mbokotwa or Klein Tsomo River, all of which drain into the Tsomo River.

Many of these valleys are quite narrow at the entrance, and widen out beneath the mountains; vast quantities of lava fragments are brought down by the rivers, and the numerous homesteads testify to the fertility of the soil, in marked contrast to those farms farther to the south which are located upon the Molteno Beds.

The variation in the Cave Sandstone from Raasay on to Xalanga Peak is described later on, when treating of the volcanic rocks of Elliot, but there is only one point which might be referred to. Throughout the Elliot district the Cave Sandstone is always a thick massive bed of rock, but just below Xalanga Peak portions of it have been replaced by thin yellow sandstones and purple mudstones. The replacement only occurs over a very short distance and in a very irregular manner, but it is noticeable that in Matatiele the Cave Sandstone is sometimes replaced by red clay, often mottled with green, or alternating with light-blue clay.*

The Red Beds in the west of Elliot require no further detailed description; when followed to the Wodehouse boundary they still retain their thickness of 1,500 feet, which is in agreement with the measurement made by Dunn near Indwe†; his value of 300 feet for the Cave Sandstone being practically the same as that noticed on the south-west of Xalanga Peak.

THE VOLCANOES AND VOLCANIC ROCKS OF ELLIOT.

Resting upon, and sometimes interbedded with the Cave Sandstone are bedded lavas and occasionally stratified ash, which form the highest portions of the Drakensberg, while in the Red Beds and Cave Sandstone there are many Volcanic Necks, from which these lavas were derived.

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* Ann. Report. Geol. Commission, 1902., p. 30.

† Dunn. Report upon recent coal borings in the Camdeboo and Stormberg. 1883. p. 8.

From the Tembu Pass on the east, to Xalanga Peak on the west, no less than sixteen of these necks were noted, not including several doubtful ones. Nine of these, numbers 6-11, 13-15, are situated on a line running due east and west, from the Barkly Pass to below Waschbank Peak; the remainder occur some distance further south.

The volcanoes will be described in order from east to west, and at the same time the volcanic beds in their immediate vicinity.

Vents No. I., II., and III. occur close together on Noah's Ark Commonage, on the bank of the northern fork of the Xuka River.

No. I.—Just beyond plot 11 in the stream are two exposures of agglomerate, about 250 feet apart, consisting of blocks of sandstone, mudstone, amygdaloid, dolerite, etc., set in a yellow friable decomposed matrix. No other outcrops are seen, and the extent of the neck is quite uncertain. A dolerite dyke passes to the south-west of the exposure, and runs up to join the dolerite in No. III.

No. II. is situated on the north bank of the stream at the western end of the boundary line stretching to the top of the Gatberg. The neck is occupied by a plug of slightly columnar dolerite, which rises to a height of fully 700 feet above the riverbed, and is everywhere in contact with sandstones presumably belonging to the Red Beds, except on the north-west, where a small patch of hard blue tuff occurs. Perched up on the mass of dolerite, and surrounded on all sides by it, there is a huge monolith of what appears to be Cave Sandstone; the contacts show signs of baking. This block is more than 200 feet high on the southern face, and is really composed partly of pale fine-grained felspathic sandstone and partly of light blue agglomerate, built up almost entirely of fragments of sandstone and shale, as a rule not more than a few inches in diameter. Only occasionally was there any distinct line of demarcation between the sandstone and the agglomerate. The probable explanation is that the vent had become plugged with Cave Sandstone and agglomerate, and a later outburst (indicated by the dolerite) has ejected nearly all of the infilling material. Somewhat further east, beyond the dolerite, the Cave Sandstone occurs, projecting from the hillside in huge monoliths; the sandstone is usually yellow or pinkish, but in places it is bright red. Blue agglomerate occurs in the sandstones along joints and fissures, and appears to be intrusive. A marked example of this occurs nearly a third of a mile east of the neck; a mass of pale blue agglomerate is seen cutting almost vertically through massive red sandstone, and then spreading out like a mushroom on meeting with hard overlying yellow sandstone.

The structure of this part of the Commonage is peculiar; from the bed of the stream thick coarse pebbly grits rise up suddenly, forming a dip-slope with an angle of 30°. These grits are quite different to the usual sandstone of the Red Beds, and resemble those of the Molteno Series, yet they rise up the hill-slope to within a couple of hundred feet of the base of the Cave Sandstone, in fact the extension upwards of their denuded edges would meet the latter. The ground is obscured, and probably a reversed fault occurs here, running nearly east and west; however, as the Red Beds are 1,300 feet thick a little to the west, it is remarkable that a fault with such a throw should not be noticeable beyond the Gatberg, a couple of miles further east. Perhaps, when the ground on the Maclear side of the boundary is examined, the abnormal juxtaposition of the beds may be satisfactorily explained.

No. III.—The ridge between the two streams on Noah's Ark Commonage, near the Maclear boundary, is composed chiefly of dolerite, but on the right side of the eastern stream there is a long narrow outcrop of fine blue tuff. From its mode of occurrence all along the bank of the stream, whose bed is composed of sandstone, it would at first appear that this is a mass of interbedded tuff, were it not that at several points the pyroclastic rock is seen cutting through the sedimentary beds, which at the junction are converted to quartzite. It seems more feasible that this represents a volcanic neck, very much elongated. The dolerite forms a plug or sheet cutting through both the sandstone and agglomerate, the latter being indurated at the contact. A small amount of tuff is exposed on the north side of the dolerite, overlooking the valley leading down towards Ugie, and it is probable that the dolerite has almost entirely replaced the tuff with which the pipe was originally filled, and then spread out laterally. The sandstones around the neck must belong to the Red Beds, although, chiefly through lack of exposures, no outcrops of the purple mudstones were seen. The beds on the west of the dolerite dip away from the latter at angles as high as 20°. On the east a similar direction of dip was observed, but here angles of 50° are not uncommon. The dolerite appears to join up with a dyke which can be followed south-eastwards across the Maxongo's stream into Slang Rivier Hoek, near Elliot, where it unites with a great dyke running northwards towards Waterkloof.

No. IV. is a very peculiarly shaped neck, being more like a fissure than a pipe, although in the west of the Colony, near Sutherland, most irregularly shaped volcanic necks have been found.* It is situated upon the ridge forming the boundary between the farm Mountain Cliff and Noah's Ark Commonage, and is entirely surrounded by Cave Sandstone. In length it is almost a mile, and its usual breadth is from 40 to 50 yards, but at its southern extremity it widens to about 150 yards. At the north end tuff and coarse agglomerate occur, containing numerous blocks of amygdaloidal and doleritic lava, sandstone, purple shale, and a peculiar bluish-white quartzite, which cannot be matched amongst the rocks of the Stormberg Series. The agglomerate can be seen cutting through the Cave Sandstone in a most irregular manner, and in places great masses of sandstone are surrounded by agglomerate, and converted in great measure into quartzite.

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* *Vide* p. 43.

Cutting through the tuff and agglomerate, there are masses of amygdaloid and dolerite, which must have been at one time connected with the bedded lavas, which can be seen about half a mile to the north-west, and which are not more than 200 feet higher in altitude. In the middle and southern portions of the neck fine tuff predominates, with occasional boulders, and now and then a mass of doleritic lava. In a gorge on the east (the source of the Maxongos stream) a thin sill of dolerite is seen cutting through the Red Beds, and may be connected underground with this neck. A little to the north of the neck there is a small outcrop, not more than 20 yards across, of tuff, agglomerate, and lava, which may represent another pipe, or may perhaps be an extension of No. IV. Across the Maclear boundary another large neck can be seen, but which was not examined. It is interesting to note that all these necks are situated on a line running about 10 or 15 degrees west of north, and that the long axis of No. IV. coincides with this direction.

No. V. is quite close at hand, not more than 150 yards to the west of No. IV. It forms a prominent ridge between two small streams, and has a length of about 150 yards and a breadth of 20. Blue tuff, rather coarse in places, forms the greater part of the neck, but the south-west portion is a plug of amygdaloidal lava, compact in places.

No. VI. is the largest and most important of all the necks, as from it have been derived the great bulk of the ash and lava beds for many miles around it. It has a length of nearly one and a half miles, with an average breadth of one quarter of a mile, and is located on the north-east corner of Tulloch, to the right of the Barkly Pass. Surrounding it is Cave Sandstone, while but half a mile to the north-west there is a great ridge, forming the divisional boundary and composed of volcanic beds, a tongue of which extends south-westwards to meet the neck along the Tulloch-Scarba fence. The ground is very uneven and cut into by a number of streams, so that good sections are afforded, laying clear the connection of the contents of the pipe with the sedimentary and volcanic beds. The longer axis of the neck trends about north-north-west, and the north-north-west portion is almost entirely filled with an extremely fine-grained blue tuff, remarkably hard and difficult to break. It is often vesicular, with numerous cavities and cracks, filled chiefly with chalcedony. At some places it is fine-grained and flinty, at others it contains abundant small concretions, up to the size of a small marble and of the same material as the matrix. Along the north-east boundary of the pipe there is a thin dyke of compact fine-grained dolerite, which has evidently been intruded between the enclosing wall of Cave Sandstone and the infilling of tuff. At several other points outcrops of dolerite occur, and in every case the dolerite is seen to be intrusive in the tuff, and to ramify through it in a very irregular manner. At the middle of the neck a considerable area of vesicular lava occurs, intrusive also in the tuff, and identical with that capping the hill-top a hundred yards or so away.

On the west and south-west there are coarse agglomerates, with abundant blocks of amygdaloid, compact lava, dolerite, compact blue tuff, grey and red bedded ash, white and pinkish Cave Sandstone, blue and purple shale (often flinty), and occasional fragments of bluish-white quartzite. The blocks are angular and subangular, often many feet across, and the agglomerate is pierced by masses of amygdaloid and dolerite.

At the extreme south-south-east end of the neck, just within the boundary of the farm Scarba, there is a plug of columnar dolerite, forming a rounded hill. The columns are not parallel, but diverge outwards as they rise, and this dolerite seems to have been connected at one time with a columnar mass of dolerite seen below a great cliff of bedded lavas. As seen from the west, this latter mass appears to be a bed of compact columnar lava, but its true nature is shown in a cliff-section on the south side of the hill. Here it is seen to be wedge-shaped, and to penetrate the lavas for a short distance; closer investigation reveals that it is later than the latter, and must have been forced in when the pressure in the vent had been much increased by the great pile of ejected material surrounding the volcano. We can distinguish three stages of activity in this volcano:—first the ejection of a vast quantity of fragmental material, forming a thick bed of stratified ash for many miles around; then we have the pouring out of a vast thickness of lava, amygdaloidal and doleritic; and lastly the intrusion of a compact crystalline dolerite. Even at some distance away towards the east thin tongues and dykes of dolerite penetrate upwards through the bedded lavas.

The ashes which were ejected at first form a great bed resting upon the Cave Sandstone and overlain by lavas; it attains its greatest thickness of 350 feet at the extreme north of Tulloch, and thins slightly to the south-east on Glenmore (Barkly East); at the south-east end of Scarba it thins out still more, and is about 80 feet thick on the farm Tembu Pass. Here, however, it does not rest upon the Cave Sandstone directly, and the sections are so interesting as to need detailed description. From Mount Rose (in Elliot) a bridle path crosses over into Barkly East, the track passing across a ridge of Cave Sandstone, flanked on either side by towering masses of volcanic beds, the gap being known as the Tembu Pass. On the west of the Pass the following section occurs:—

5.	Rudely columnar and bedded lavas ... about	350 feet.
4.	Purple stratified ash	80 "
3.	Cave Sandstone	30 "
2.	Bedded lavas	50 "
1.	Cave Sandstone	800 "

Several fine cliff sections showing No. 2, resting upon No. 1, are visible, and the junction is beautifully sharp.

The base of the lowest group of lavas is composed of very vesicular material, with large cavities filled with zeolites, but a few feet above the base the rock becomes more compact. Numerous blocks of sandstone, now altered to dark quartzite, occur in the lavas, showing that the centre of ejection could not have been far distant.

The bed of sandstone above the lowest group of lavas is quite free from volcanic products, except near the top, where it passes rapidly into grey and then into purple ash. The lower lava sheet extends southwards for over a mile from the foot of the cliff, along the ridge between Waterkloof and Mount Rose, but both it and the overlying sandstone thin out and disappear towards the north-west. It is most probable that the lower lava sheets (No. 2) were not poured out from the volcano on Scarba, but from one of the necks on Mountain Cliff, possibly No. V. Later, a thin bed of Cave Sandstone was laid down upon the lava sheet, and the whole afterwards buried by material from the large pipe No. VI. On the east of the Tembu Pass the ash bed is about 50 feet thick, and rests directly upon the full thickness of the Cave Sandstone. About half a mile further east a lava bed makes its appearance between the ash bed and the Cave Sandstone, but a little distance further on this bed of ash thins out and disappears. The ash bed is thus found to extend towards the south-east for a distance of three miles from No. VI. before it dies out; it extends towards the north many miles into the Barkly East district. Towards the west, the nearest point at which the volcanic beds occur is about six miles away, on Balclutha, but no ash bed is present; the lavas rest directly upon the Cave Sandstone.

A bed of white ash of very limited extent, and never thicker than three feet, occurs on Glenalvon, the farm next to Balclutha, about 100 feet below the base of the volcanic beds, and may have been derived from materials ejected by the Tulloch volcano. The ash bed on Tulloch, Scarba, etc., is very constant in composition; at its base it is light greenish-blue, and from sections seen on Glenmore, just within the Barkly East Division, it appears to pass downwards insensibly into the Cave Sandstone. The transition takes place in a short distance, and it is evident that the volcanic material was ejected in such great quantities as to predominate in a very short time over the sediment which was being laid down at that period. This blue ash is never more than twenty feet or so in thickness, and passes upwards into a bright, brick-red ash, full of small fragments of sandstone and shale, with occasional angular blocks of sandstone and lava. The bedding is not well seen, for the rock is very uniform in character; on weathered surfaces it very much resembles a soft friable red sandstone, and splits very readily in a horizontal direction. The volcanic neck on Tulloch cuts right through the Cave Sandstone, and through this bed of ash, as is well seen at its south-eastern extremity.

A very interesting occurrence of ash interbedded in the Cave Sandstone is met with on the south-west of Scarba, on a gentle hill-slope facing east; cropping out as it does along the hillside for about 200 yards, with sandstone higher up as well as lower down, it is evidently a lenticular bed of ash with a maximum thickness of 15 feet. The ash is bluish-green in colour, and contains fragments of carbonised wood, thus being an unusual type of tuff. A small outcrop of very fine-grained dolerite associated with the ash probably represents a contemporaneous lava flow. The volcanic material has probably been derived from the Tulloch volcano, which lies just over two miles to the north. The even distribution of the ash around the volcano, the interstratification of Cave Sandstone with ash and lava, and the regularity of the bedding-planes all point to the agency of water, and it is most probable that the lava flows, or at least the basal ones, must have been subaqueous. The intercalation of beds of Cave Sandstone with the lava that occurs around Waschbank and Xalanga Peaks, and which is described later on, points to the same conclusion, while Dunn* has advanced a similar view in the case of the Stormberg area. It is probable that near the close of Cave Sandstone times, a series of sub-aqueous volcanoes came into existence, and that beds of tuff were laid down beneath the water, and were occasionally covered again by sediment free from ejected material; these events culminated with lava flows, at first sub-aqueous, and possibly later on, when the water had been displaced, sub-aerial. How thick these lavas were is uncertain; in Elliot, at least, their maximum thickness lies between 1,500 and 2,000 feet.

No. VII is a plug-like mass of dolerite situated on Barkly Pass Extension, about half a mile from the north end of No. VI

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* Report on Stormberg Coal Fields, p. 10.

Situated on a steep slope of Cave Sandstone, it rises as a dome-shaped mass of dolerite with fine regular vertical columns, a rather curious feature, for one would expect the columns to lie horizontally and to converge from the walls towards the centre of the pipe. The plug goes down vertically, and for a distance of a foot or so from the dolerite the sandstone is baked; the plan of the neck is oval, measuring about 100 yards by 50. The dolerite is massive, thoroughly crystalline and medium grained; a narrow dyke running from the hotel on the top of the Fetcani Pass to the edge of No. VI passes within a short distance of No. VII.

Nos. VIII, IX, and X occur on the farm Ballater, almost directly beneath the fine precipice of the Tafelberg. All three are surrounded by Cave Sandstone, and lie near the base of the volcanic rocks, the debris from which obscures the northern boundaries of the pipes.

No. VIII is probably not more than 15 yards across, being only well defined at the south end, where the Cave Sandstone is baked for a short distance to a hard quartzite. It is filled with compact blue tuff, fine-grained, weathering spheroidally, and containing large blocks of red and white sandstone, tuff, and vesicular and compact lava. A thin dolerite dyke not more than two feet in width cuts through the Cave Sandstone on its southern edge, and is probably connected with this neck. Tuff occurs again about ten yards to the north-east, and may belong to another and smaller neck, but possibly it is only a lenticular mass interbedded in the Cave Sandstone.

No. IX is the largest of the three; it is about 200 yards in diameter, and occurs about a quarter of a mile to the west of No. VIII. The Cave Sandstone is seen to surround it on three sides, but the boundary on the north is uncertain. The pipe is filled with medium-grained light blue tuff, with occasional blocks of sandstone, lava, etc., usually angular or sub-angular. A sill of dolerite about ten feet in thickness and columnar in places cuts right through the neck, having a high dip towards the north. The dolerite can be followed eastwards past No. VIII for nearly a mile, and in the kloofs is seen coming up nearly vertically, and then cutting almost horizontally through the upper beds of the Cave Sandstone. The dyke then turns southwards and cuts through the Red Beds on the east side of Ballater, and at last joins up with a great sheet of coarse-grained dolerite, capping the ridge called Jopo. When traced westwards the dolerite appears to continue for a hundred and fifty yards from No. IX., ending close up to the edge of No. X.

Whether the northern edge of No. IX is covered by the lavas of the mountain range is uncertain, but a mass of dolerite appears to issue from the vent, rising in a north-westerly direction, and then cutting diagonally through the bedded lavas at an angle of about 10 degrees; afterwards it seems to spread out laterally and form part of the lava flows. Hence it seems most probable that the volcano, after having been covered up with about 200 feet of lavas, burst into renewed activity, ejected a stream of lava which penetrated the covering, and then finally became quiescent, and was buried up by the lavas from other centres. That this volcano commenced work before the deposition of the Cave Sandstone was completed, is proved by the occurrence on the east side of the neck of thin bands of tuff alternating with sandstone, the one passing insensibly into the other. The exposures are rather limited, but there appear to be no bombs interbedded in the Cave Sandstone, the material being solely fragmental.

No. X is probably not more than 60 yards across, and is composed of blue tuff. The only point of interest is the high dip inwards of the Cave Sandstone on the south-east side of the pipe. About a mile farther west, on the farm Balachaolish, just below Tafelberg, there occurs a peculiar sheet-like mass of dolerite not more than fifty feet in thickness, resting upon Cave Sandstone. Good sections are afforded along the banks of the stream running down from the slopes of Tafelberg, the bed having been excavated down through the dolerite into the underlying sandstone. Higher up the mountain side the Cave Sandstone is seen again, and it appears as if the dolerite is interbedded with it. The dolerite is seemingly lenticular, and represents an overflow from one of the volcanic necks just described farther to the east, a view confirmed by the occasionally vesicular character of the igneous rock. It appears then that the volcanos Nos. VIII—X came into action during Cave Sandstone times, and probably became extinct after a very short period of activity. The Cave Sandstone here is much thinner than farther eastwards, having a thickness of not more than 500 feet. Above comes a great pile of lavas, of which not less than 1,500 feet are exposed on Tafelberg. The flat top of this mountain is due to a thick bed of compact and beautifully columnar lava.

No. XI is a small neck of fine tuff perched on a spur of the Drakensberg on the farm Struman, and from a distance resembling an outlier of Cave Sandstone.

No. XII.—On the north-east corner of Dorasmhor there is a curious conical hill rising about four hundred feet above the surrounding tract, which consists of Red Beds. On a ridge not half a mile to the west a good section of the Red Beds sandstones and mudstones is seen, and the contrast with this white hill is very marked. On the north side there are horizontal yellow sandstones and purple mudstones, but near the summit these are disturbed, and dip south at a steep angle. On the south and east side there is massive fine-grained yellow felspathic sandstone practically identical with Cave Sandstone; and of which a vertical extent of at least 200 feet is visible. On the south-west side, and again on the north-west and north, are outcrops of a peculiar whitish quartzite, composed of small angular grains of glassy quartz set in a white ground-mass; the rock resembles a surface quartzite. This bed attains a thickness of about seven feet on the north, and grades insensibly above and below into soft sandstones, in which, as in the quartzite, were found fragments of silicified wood. The quartzite on the north, when followed from west to east, ends quite abruptly, and soft sandstones take its place, but the exposures are not sufficient to explain the change. At the summit of the conical hill there are patches of a peculiar greenish-blue tuff-like rock, though the fragments, instead of being angular, appear rather rounded and worn, and igneous rocks are entirely absent. Its mode of occurrence also is peculiar; in places it passes insensibly into a hard white sandstone, while elsewhere it appears to surround fragments and boulders of the latter. Perhaps the explanation is that the volcano came into existence at an early period, and became extinct just at the commencement of the deposition of the Cave Sandstone. The pipe was then filled in with sediment and with rolled fragments and detritus of tuff, and finally buried beneath Cave Sandstone and lava flows. The white quartzite may perhaps have been built up of material ejected by the volcano, for it has not the slightest resemblance to any rock found among the Red Beds. The occurrence of silicified wood in the quartzite is interesting, because it is very rarely found in the Red Beds.

Nos. XIII and XIV both occur on the farm Raasay on opposite banks of a tributary of the Xentu stream.

No. XIII is very prominent and conspicuous, forming a beautiful conical white peak on a ridge composed of Red Beds in the fork between two streams. Good sections shewing the contact with the sedimentary rocks are revealed in the banks of the stream; the Red Beds are practically undisturbed; and the neck cuts down nearly vertically through the horizontal sandstones and purple mudstones of that series. The pipe is almost circular in section, and is 200 yards in diameter; it is filled with massive fine light blue tuff, which weathers white, and forms such a contrast to the dark-coloured surrounding rocks.

No. XIV is situated not more than three-quarters of a mile from the former, and overlooks the farm-house of Raasay on the bank of the Xentu stream. It cuts through both Red Beds and Cave Sandstone, and consists of both light blue tuff and dark coarse agglomerate, with numerous igneous blocks.

Before describing the last two volcanic necks it is advisable to give an account of the Cave Sandstone and lavas in the north-west corner of Elliot, from Raasay to the Wodehouse boundary, below Xalanga Peak. West of Raasay, as one goes up the narrow valley of the Xentu stream, the Cave Sandstone diminishes in thickness, and on the farm Radobil there are two beds of sandstone, separated by from 100 to 150 feet of lavas. The lower bed varies from 50 to 100 feet, and forms a well-defined krantz, especially on the farm Rzip, where the two branches of the Xentu stream have cut narrow gorges through the Cave Sandstone. As it is followed on the right bank of the Xentu stream along the ridge separating the farm Radobil from Moina the bed becomes thinner, though still retaining its characteristic white colour and massive appearance On the farm Moina the white sandstone disappears and the lavas rest directly upon the Red Beds. The upper bed of Cave Sandstone is seen only at intervals on the hill-slopes on Radobil and Rzip, owing to the large amount of fallen material from the cliffs of lava which hem in the valleys. It has a thickness of about 50 feet above the farm-house on Rzip, but when followed up the valley of the Qokama stream it thickens, until at the source of the river on the farm Celtschberg it attains a thickness of between 250 and 300 feet. Owing to the steepness of the sides of the ravine the Cave Sandstone does not form any cliff, as on Rzip. From Celtschberg the bed can be followed round below the lofty cliffs of Xalanga Peak, leaving a small outlier on the spur above the farm Minard. When the lower bed of Cave Sandstone disappears on Moina, the basement lava flows (between the upper and lower beds of Cave Sandstone) are split up by a parting of sandstones and shaly beds, which have characters resembling those of the uppermost portions of the Red Beds rather than those of the Cave Sandstone. This bed is never more than fifty feet thick, but it can be followed round the valley of the Qokama, finally disappearing on the west of Minard, while further to the south-east on a spur of the mountains its position is taken by white sandstone, more like the Cave Sandstone.

Just below Xalanga Peak the Cave Sandstone is well developed, and is in two portions, the lower 200 feet thick, the upper 50 feet, with a bed of compact doleritic lava 50 feet thick separating them. In the gorge of the stream flowing down from Xalanga Peak to Glen Lion the upper bed of sandstone disappears quite abruptly, while the lower bed occurs at a level of about one hundred feet higher on the west bank, indicating the presence of a fault. The occurrence of isolated masses of sandstone, apparently lenticular patches, in the lavas, shows that the regular conditions of deposition did not obtain on the east side of the fault. The top of the Cave Sandstone comes lower and lower down, although the beds are apparently horizontal, and in a fine section at a waterfall the uneven surface of the sandstone is seen, upon which the lavas rest. The igneous rock behaves almost like an intrusive mass, passing into a horizontal fissure, while small tongues of the sandstone pass into the lava, and have been baked to a dark quartzite. From the truncation of planes of bedding it seems as if the irregular surface of the Cave Sandstone has been caused by erosion or weathering. In the east branch of the stream flowing down to Glen Lion the beds are tilted at about 35° to the south-south-west and the Cave Sandstone disappears, the lavas now resting horizontally upon the Red Beds. The highest member of the latter is a massive bright red sandstone of great thickness, but as the junction is followed round to the east, the doleritic lava is found to rest upon lower and lower members of the Red Beds. Afterwards the junction rises again and the Cave Sandstone is found once more. The explanation probably is that the beds were disturbed by local earth movements, so that erosion occurred at different points, and lava flows covered up the surface thus modified. Afterwards there was a deposition of silt again, usually continuous, but sometimes only local, the sedimentation being interrupted in places by lava flows. Elevation or subsidence on a large scale may also have considerably modified the condition of sedimentation.

The Cave Sandstone where intercalated between the lava flows is almost always, even in the neighbourhood of a volcanic neck, free from ejected material, and no bombs were ever observed, such as Dunn has recorded* from the same horizon some distance further west, neither were any beds of vocanic ash seen between the lava flows in the west of Elliot.

We may now return to the description of the last two volcanic necks, Nos. XV and XVI.

No. XV occurs on the extreme west of Radobil, on the north bank of the Xentu stream. It is roughly oval in plan and about 250 yards in length, but owing to the irregularity of the ground, only approximate measurements are possible. The greater part of the contents is fine blue tuff, but nearer the centre it is much coarser, with large angular blocks of sandstone and lava, while on the west side the igneous material predominates. Two streams cut through the pipe, and occurring, as it does, on a steep hill-slope, fair sections are afforded. The Cave Sandstone at this point is split up by a bed of doleritic lava, as mentioned above, and it is interesting to find that the neck cuts through both the beds of sandstone and through the igneous sheet as well. Here, then, we have one of the volcanic necks from which in all probability the upper lava streams have been derived. Close at hand there are beautiful cliffs of lava rising up to a considerable altitude; only a few miles away is Waschbank Peak, and it is probable that much of the material building up these mountain ranges has been derived from this pipe.

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* Dunn. Report on Stormberg Coal Fields, p. 10, 1878.

No. XVI is a funnel-shaped mass of light blue medium-grained tuff situated a little over a mile south-south-west of Xalanga Peak, and almost on the Wodehouse boundary. It occurs low down in the gorge of the Entungela stream, a river which flows down through 'Mbokotwa Commonage. The neck is oval, about 350 yards long and 150 yards across, with its longer axis bearing north-west and south-east. It is cut through by two streams, and on the ridge between them a good transverse section of the pipe is afforded. On the north side the beds for about 250 yards have a high dip inwards towards the neck, the dip gradually increasing until it becomes almost as great as that of the wall of the pipe itself. By this dip, reaching 45° at the maximum, the topmost members of the Red Beds are brought down several hundred feet into contact with the tuff, and had not denudation been carried quite so far, the outlying Cave Sandstone, forming a krantz at the head of the gorge, would have formed the northern boundary of the neck. On the north-west the dip is also high, but on the south and west the beds are only slightly disturbed. On a shoulder a little to the east of the neck there is a small exposure of coarse agglomerate, with blocks of lava, sandstone, tuff, etc., which may represent another pipe or may be connected with the one just described.

Generally speaking, the dip of the beds in the Drakensberg is always inwards towards the north; at the Barkly Pass this dip is not much, but at several places farther west the angle may be as great as five degrees. At the Barkly Pass the base of the lavas attains its greatest altitude, *i.e.*, 7,200 feet; eastwards towards the Tembu Pass the level is somewhat lower, but on the west the dip towards the north-west is very plainly seen. The lavas come down lower and lower as we proceed westwards along the range, and reach their minimum elevation below Waschbank Peak (5,750 feet). The beds here become practically horizontal, but rise again towards the south; the level of their base at Xalanga Peak is 6,300 feet. Waschbank Peak is situated practically at a centre of subsidence of the lavas, for further to the west, in Wodehouse, according to Dunn, the elevation of these rocks above the sea-level increases.

The lithological characters of the lavas in the Elliot District hardly need any description; in every way they are identical with those described by Mr. Schwarz from Matatiele.* All types are probably represented, though no thin sections have yet been examined under the microscope. Taken as a whole, compact lavas predominate over amygdaloid, though there are often great thicknesses of massive lavas with horizontal bands of vesicles; as a rule, the individual flows are many feet in thickness. Much light should be obtained by an examination of the

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* Annual Report of the Geol. Commission, 1902.

Barkly East Division on the question whether the Drakensberg Volcanoes are arranged along definite lines or scattered irregularly over a considerable tract of country, as is the case with those of Fifeshire.*

Probably there are numerous Volcanic Necks still buried beneath the lavas, and not yet brought to light by the action of denudation.

THE DOLERITES OF ELLIOT AND XALANGA.

Dolerite intrusions are very abundant, especially towards the south and south-west of this area, and there is only one small tract of country, the west portion of Gubenxa, from which igneous rock is practically absent.

These rocks have not yet been examined under the microscope, but they may be divided into two classes, though evidence in the field goes to show that they both belong to the same period of intrusion.

(A) The dolerites of the Gubenxa district.

(B) Those of the remainder of Elliot and Xalanga, but which occur also in Wodehouse, Glen Grey, St. Mark's, and Engcobo.

The former are apparently identical with the normal type of the Karroo dolerites and with those met with further to the north-east, in Matatiele. In Gubenxa, dykes of this dolerite often decompose very readily, their position being marked by a slight trough in the sandstones, in which reddish earthy material occurs.

The second type is a coarse-grained dolerite, which on weathering shows a pitted surface, the hollows being of a lighter colour than the rest of the surface. On a fresh fracture large felspar crystals appear, surrounded by a ground-mass containing large pale yellow-green augites and some iron ores. In some dykes there is very little ilmenite, but in others, as, for instance, those a few miles south of Cala, the dolerite is crowded with plates of that material, often over one-quarter of an inch in diameter. This coarse-grained type of dolerite is not confined to the thicker dykes and sheets, but is found even in narrow dykes, the rock being uniform in texture almost up to the very edge of the intrusion.

In the district of Nyelasa, south of Cala, almost on the St. Mark's boundary, veins of fine-grained dolerite a few inches thick traverse a sheet of coarse-grained rock. At no place were acid veins noted, though these are of common occurrence in the Karroo and in the coastal districts of the Transkei.

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* A. Geikie. Memoirs of the Geological Survey of Scotland, 1902. Geology of Eastern Fife.

There is no regularity in the intrusions in this area; great dykes cut through the beds, and give rise to thick sheets, which often end abruptly or dip downwards again into the earth. Dykes ramify though the strata and apparently cross one another, but on examination they are found to be of the same age and never to cut one another.

There is a great tendency for the thick dykes to run in closed curves, a feature which has already been noted by Dunn* in the Queenstown district, the dip of the dyke being usually inwards towards the centre. The form of the dolerite is probably funnel-shaped, and it is found that at Indwe and at Cala the central mass of sedimentary rock has been elevated or faulted up. The annular dyke which forms the boundary of the low ground around Cala is rather irregular in outline; but the upthrow, though usually not much on the north-east side, is fully 150 feet on the south and south-east, and from 350 to 400 on the west.

It might be noted at this place that faulting is not uncommon in the strata, and almost invariably the fault-faces are separated by a dyke of dolerite.

As the number of intrusions in the district is very large, only some of the more important ones will be mentioned in detail, beginning from the south-west.

At Askeaton there is a great dyke of dolerite cutting across the Indwana River, and then giving rise to a sheet which caps the Umtingwevu mountains. Another great sheet of dolerite forms the high ground between Askeaton and Garry Owen, into which the Indwana River has cut to a depth of over three hundred feet. A third sheet of dolerite is seen at Rebel's Kloof, capping the hills to the south, over which the road from Cala to Askeaton passes. On the western boundary of Xalanga, from Umgwalana nek to Hota, the summit of the dividing range is capped with dolerite, apparently lenticular in form, for almost at its southern extremity one dome is capped with about 500 feet of igneous rock, while next to it is a flat-topped peak of sedimentary rocks, indicating the rapid thinning out of the dolerite. Towards the north, up the Tsomo Valley, dolerite sheets are numerous; at Clutha, just within the Elliot Division, no less than six sheets can be counted on the hillside above the river, due to the splitting up of a great sheet a little to the south-east. On 'Mbokotwa Commonage the great hill called Aasvogel Kop consists of Red Beds overlain by several hundred feet of dolerite. Between Ida ('Mbokotwa Commonage) and Los Kop there are hardly any sheets, but the strata are traversed by a network of dykes. There appears to be no general rule for the directions of these dykes, but the great majority run either north-west or north-east, or they often start off approximately north and south, and then incline towards the east or west.

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* Report on the Stormberg Coal Fields, p. 15, 1878.

The high ground on the left bank of the Umgwali River, from the Cala Pass to Zadungeni, is formed of a sheet of dolerite, which splits and gives off lesser sheets in a most irregular manner. Between the Blaauw Valley Spruit and the Slang River there is a peculiar flat-topped ridge, very narrow in compaarison with its length; it trends south-east. On the south-west-side there are horizontal strata belonging to the Molteno Beds, while on the north-east there is almost nothing else but dolerite. This peculiarity is due to the sudden dipping down of the dolerite towards the south-west, so that it is not visible in the Blaauw Valley. The sheet as it emerges flattens out, and becomes thicker, so that towards the north-east an area of about 45 square miles, all high ground, is formed of dolerite. Through this hilly ground the Slang River has cut its tortuous course, and has almost succeeded in sawing its way right through the dolerite into the Indwe Sandstone below. The winding of the river, from which it has obtained its name, is most peculiar; at one place, the south-west corner of Bloem Vley, there are points separated by a distance of two miles when measured along the stream which are only a little over one hundred yards apart in a direct line, the channel being cut in solid dolerite, hills of which rise to a height of about 1,000 feet above the river. The extrusion of this vast amount of material has apparently caused the sinking of the strata below the sheet, for the dip around the outcrop of the dolerite is usually inwards. The dolerite is evidently lenticular, and on its eastern border it has been split up into several sheets, as can be seen in the Xuka Valley.

In the Elliot Division there is a sheet of dolerite which stretches in a south-east north-west direction from the Engcobo boundary at Welbekent and Rooipoort to Navar, and beyond; it cuts through Red Beds at Los Kop and Jopo, and through the Cave Sandstone on Ballater. It is of considerable thickness, usually 300 feet or more, and unites with the north-east end of the Slang River intrusion just described; in the Xuka River Valley it splits, and gives rise to two lower sheets and one upper one. The ground between Maxongo's Hoek and Xuka Drift is much intersected with dolerite intrusions, chiefly sheets with a high dip towards the north-west.

In the east of Gubenxa there is a perfect network of dolerite dykes and sheets, mostly of the Karroo type, but at its south-west corner a mixture of both the Karroo and Xalanga types occurs. Some of the dykes in the Drakensberg have already been mentioned in the description of the volcanic rocks, and their relationship to the latter discussed. One very prominent dyke forms a spur almost on the Wodehouse boundary, then spreads out beneath the Cave Sandstone, and as it penetrates this rock it becomes thin, and finally dies out almost at the base of the lava beds.

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